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DEPARTMENT OF NATURAL RESOURCES

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# MANGANESE IN CALIFORNIA

BULLETIN No. 125

ISSUED BY THE  
STATE DIVISION OF MINES  
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DEPARTMENT OF NATURAL RESOURCES

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BULLETIN No. 125

[ DECEMBER, 1943

# MANGANESE IN CALIFORNIA

INCLUDING OUTLINE GEOLOGIC MAP OF  
CALIFORNIA SHOWING LOCATIONS  
OF MANGANESE PROPERTIES

PREPARED UNDER THE DIRECTION OF  
OLAF P. JENKINS



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DEPARTMENT OF MINING, STANFORD UNIVERSITY



## LETTER OF TRANSMITTAL

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*To His Excellency, THE HONORABLE EARL WARREN,*  
Governor of the State of California

SIR: I have the honor to transmit herewith Bulletin No. 125 of the Division of Mines of the Department of Natural Resources on "Manganese in California."

During time of war when the steel industry is hard pressed for essential war materials, *manganese* becomes critically strategic in the United States, because imports can not be depended upon and domestic sources are insufficient. Every deposit in the State, whether large or small, whether of high or low grade becomes a possible potential source upon which the industry may draw. During World War I the California State Mining Bureau issued Bulletin No. 76 "Manganese and Chromium in California" which has proved to be a boon to the industry. Again, during World War II, the nation has returned to this same quest only with a more thorough search to meet a more critical situation. Furthermore, the utilization of manganese in making dry batteries has given new life to some of the California mines where the ores are particularly well suited to this industry.

Bulletin No. 125 represents not only a review of the results of the earlier search but a summary of more recent investigations carried on by Federal agencies as well as by the staff of the Division of Mines. The Bulletin contains several articles, each written on an important phase of the subject by an outstanding authority. The contributing authors and their affiliations, when the work was carried on, are as follows: Parker D. Trask, Ivan F. Wilson, and Frank S. Simons of the Geological Survey, United States Department of the Interior; N. L. Taliaferro, Frank S. Hudson, and Theo H. Crook of the Department of Geological Sciences, University of California; O. Cutler Shepard and Robert S. Kroger of the Department of Mining, Stanford University.

The securing of cooperation from these several agencies and persons, the assemblage of material to form one volume, and the preparation of "Economic Mineral Map of California No. 5—Manganese," which is included in the pocket of this Bulletin, has been done under the direction of Olaf P. Jenkins, Supervising Geologist, with the editorial assistance of Elisabeth L. Egenhoff, both members of the staff of the Geologic Branch of the Division of Mines.

"Manganese in California" should stand for many years to come as a source for information and as a guide in making new discoveries, for this Bulletin emphasizes in particular the geological occurrence, distribution and formation of the ore.

Respectfully submitted,

WALTER W. BRADLEY  
State Mineralogist

San Francisco, December 3, 1943



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## PREFACE

It is the purpose of Bulletin 125, *Manganese in California*, to assemble the data and sources of data on all noteworthy deposits of manganese in California; to discuss their utilization, the history, and the place these deposits occupy in the whole manganese industry; to describe the general features of the principal commercial manganese minerals and their geologic occurrence; and to discuss the characteristics, origin, and geology of the manganese deposits which occur particularly in the State of California. To accomplish this multiple purpose, several authors have shared in the undertaking, contributing papers on subjects to which each has devoted much time and careful study.

The development of domestic manganese became a critical issue during World War I, and in 1917 and 1918 investigations were made of the manganese deposits of California through the efforts of the Committee on Scientific Research of the State Council of Defense. The history of this work is summarized in the following paragraphs supplied by Dr. George D. Louderback:<sup>1</sup>

### WAR MINERALS INVESTIGATION IN CALIFORNIA 1917-1919

Early in May 1917 the Committee on Scientific Research of the State Council of Defense set up a Committee on Geology and Mineral Resources consisting of J. C. Branner, F. W. Bradley, and G. D. Louderback. It held its first meeting on May 8 with J. C. Branner as Chairman and G. D. Louderback as Secretary. After extended discussion of the mineral needs of State and Nation, the Secretary was instructed to inquire into any proposed activities of the various State and National organizations which might operate in the California field, so that a satisfactory basis for the Committee's activity might be determined. Later in the month Dr. Branner found it necessary to go East on an extended trip, and Dr. Louderback was appointed Chairman of the committee.

While the committee was called upon to advise concerning all of the California minerals of value in the war, except petroleum, which was assigned to a special committee, a study of needs and possibilities showed that a direct investigation of the manganese resources of the State gave most promise of important returns. The Committee on Scientific Research made a small appropriation for field expenses, and the Chairman of the Committee on Geology and Mineral Resources secured the services of volunteer assistants for the field work. These were originally Dr. E. F. Davis, Instructor in Geology, and F. S. Hudson, and later in the field season N. L. Taliaferro, the latter two being graduate students at the University of California. They used part of the summer vacation of 1917 and other spare time for field examinations. Early in 1918 a report was completed giving a general survey of the manganese situation in California, a tabular summary of properties examined showing transportation facilities, output, ore values and probable reserves, and also descriptive reports of each of the properties examined in the field and a map of the State with locations spotted. These reports were not published but were supplied to the U. S. Geological Survey, the U. S. Bureau of Mines and the National Research Council for their information and for the administrative use of various agencies. The general part of the report on the California manganese situation was published in the Mining and Scientific Press of March 30, 1918. The specific reports covered more than 90 prospects and mines and the government agencies to which they were sent expressed the opinion that the work was important and should be continued.

In April 1918 the Committee on Geology and Mineral Resources was enlarged with the following personnel: F. W. Bradley, J. C. Branner, L. H. Duschak, D. M. Folsom, Fletcher Hamilton, G. D. Louderback (Chairman), T. A. Rickard, and Bailey Willis.

In the spring of 1918 the U. S. Geological Survey requested the Chairman to undertake an investigation of the chromite resources of the Sierra Nevada and extended this later to include the Coast Ranges. Later in the summer the Survey asked that the original manganese investigation be extended to all of California except the extreme southeast portion which they had assigned to a party working in Arizona. Then the U. S. Bureau of Mines asked the Chairman to take charge of their manganese survey to cover all of California. As a result of these requests a cooperative arrangement was made in the summer of 1918 to cover the chrome and manganese resources of the State. The Chairman of the Committee undertook the work for the Geological Survey on a personal government contract, the cost being estimated to cover the Survey's share of

<sup>1</sup> Personal communication by Dr. George D. Louderback, Department of Geological Sciences, University of California, Berkeley, October 25, 1943.

the cooperative undertaking. The Bureau of Mines appointed the Chairman a Consulting Mining Engineer (\$1.00 per year) in charge of its work, and appointed the field party chiefs he had selected Junior Engineers with salary for three months and a per diem for field expenses. It also made available an office secretary and the services of its local station under the direction of L. H. Duschak for making desired assays and analyses, and cooperating in solving various problems of the industry. The Committee on Scientific Research of the State Council of Defense appropriated funds which were available for the employment of other field and office assistants and for expenses. The Department of Agriculture of the University of California made two automobiles available for field travel, and the University supplied office and laboratory space and other facilities. Thus several Federal and State agencies combined their efforts under one management for the purpose of achieving maximum efficiency and avoiding duplication of activities.

Field parties were organized as follows: Northern Coast Ranges, E. F. Davis in charge, A. O. Woodford, assistant; southern Coast Ranges and southeastern California, F. S. Hudson in charge, Glenn Alvey assistant; Sierra Nevada, N. L. Taliaferro, in charge, Theo Crook, assistant; Klamath Mountains, R. R. Morse in charge, Merlyn Morse, assistant.

These parties completed their field campaigns about October 1, 1918, and then a party was made up for the desert region of southeastern California, at first in two sections:

1) R. R. Morse in charge, Merlyn Morse assistant.

2) F. S. Hudson in charge, C. E. Meek assistant.

Later, when the two assistants entered military service, the work was completed by Messrs. Hudson and Morse working together.

During all this time the office and laboratory work became very extensive. A large volume of correspondence developed with prospectors, miners, smeltermen, government offices, etc. Many visitors called for advice and information. Questions concerning conditions and welfare of the industry, discriminations, effects of Government orders, schedules and priorities, draft deferments, etc. were reported on or otherwise handled at request of industry or Government agencies, useful researches were carried out by individuals and organizations at the request of the Chairman.

Throughout the period of field work the Government bureaus were continually supplied with brief reports on printed forms as they became available. When the war ended many of the more complete descriptive reports had not been finished; however, their preparation was completed as soon as feasible and copies furnished to the U. S. Geological Survey and the U. S. Bureau of Mines. It was considered important to have all of the material on file in Washington because, as stated in the Chairman's report, with the return of peace "it is probable that all of the local industry will cease and if at a later period we should be involved in another war, or if other nations should become involved in a war with each other and cut off our supplies, or if for politico-economic reasons the foreign countries to whom we look for our supplies should restrict our imports, it would probably be necessary to revive our domestic industry, and in that case it would start right from the point where it has now stopped and our reports would indicate where operations might best be undertaken and what the prospects for supply are." This prediction has been verified.

At the same time that this work was being carried on, engineers of the State Mining Bureau visited and reported upon the various manganese and chromite properties of the State. The final results of their work, including also material contributed by "various members of the U. S. Bureau of Mines and the U. S. Geological Survey" and "notes kindly furnished by members of the staff of the Department of Geology, University of California," were all incorporated in Bulletin 76 of the California State Mining Bureau, *Manganese and Chromium in California*, by Walter W. Bradley, E. Huguenin, C. A. Logan, W. Burling Tucker, and Clarence A. Waring. Though this bulletin covered most of the important manganese and chromite deposits of the State, the original geological reports of the Council of Defense were never published in their entirety or made generally available. They are still in typewritten form in the files of the Geological Survey, the Bureau of Mines, and the State Division of Mines.

World War II brought back the critical need for the development of manganese in California. At the suggestion of the writer, and under the guidance of Professor Charles A. Dobbel, a general review of the subject of California manganese was undertaken by Robert S. Kroger in 1939. The results of his study, made largely from the earlier published and unpublished reports and from the files of the State Division of Mines, formed a thesis which was accepted in 1941 by the Department of Mining Engineering of Stanford University in partial fulfillment of the requirements for the Degree of Engineer. *History of the Manganese*

*Industry* appearing in Bulletin 125 represents a part of Mr. Kroger's thesis. Much of the other information compiled by him, especially his tabulated list of manganese properties of California, has also been used in this bulletin, modified in respect to recent developments.

As a part of the recent strategic minerals investigations by the United States Department of the Interior, Geological Survey, a thorough field study of the individual manganese deposits of California was made during 1940, 1941, and 1942. As a result of these surveys, one published report and several preliminary maps have been made available. These include:

**Hadley, J. B.**, Manganese deposits in the Paymaster mining district, Imperial County, Calif.: U. S. Geol. Survey Bull. 931-S, pp. 459-473, pls. 75-77, figs. 59-63, 1942.

**Strategic minerals investigations preliminary maps of the manganese deposits of the Black Wonder area, Santa Clara and Stanislaus Counties, California:**

1. Index map of part of northern California showing location of the Black Wonder area.
2. Map of the Black Wonder area, Calif., showing location of manganese deposits.
3. Geologic map and sections of the Jones group of manganese deposits.
4. Plan and sections of the mine workings of the Jones group of manganese deposits.
5. Geologic map and sections of the Murmac group of manganese deposits.

**Strategic minerals investigations preliminary maps of the manganese deposits of the Ladd-Buckeye area, near Tracy, California:**

1. Geologic map of the Liberty manganese mine area.
2. Plan and vertical projection of the Liberty manganese mine.
3. Geologic map and sections of the Cummings mine area.
4. Geologic plan and sections of the Cummings manganese mine.
5. Map of the underground workings of the Ladd manganese mine.
6. Geologic sections of the Ladd manganese mine.
7. Geologic map of the Buckeye mine area.
8. Mine plan and map of the north orebody in the Buckeye mine area.
9. Geologic plan and sections of the south orebody in the Buckeye mine area.
10. Geologic map of the Ladd manganese mine area, San Joaquin County, California.

The geologists engaged in these recent field investigations by the federal Geological Survey were as follows: Edgar Bowles, D. C. Cox, S. C. Creasey, M. D. Crittenden, Jr., Fred Gros, J. B. Hadley, C. B. Hunt, S. G. Lasky, John Livermore, John Nelson, W. G. Pierce, R. J. Roberts, A. F. Shride, F. S. Simons, Parker D. Trask, F. D. Trauger, C. R. Warren, J. H. Wiese, and I. F. Wilson. The work in northern California was done under the direction of Parker D. Trask. The southern California work was done under the direction of the Survey's local office in Tucson, Arizona.

As a cooperative undertaking between the United States Department of the Interior, Geological Survey, and the Geologic Branch of the California State Division of Mines, *Manganese Deposits of California—A Summary Report*, was prepared by Parker D. Trask, Ivan F. Wilson, and Frank S. Simons. This report, including *Tabulated Data on Manganese Properties of California*, constitutes one of the principal sections of Bulletin 125.

The original tabulated list of manganese properties prepared by Mr. Kroger has thus been greatly enlarged, brought up to date, and checked by field work. Miss Elisabeth L. Egenhoff has arranged the material in its final form, to correspond with other such mineral lists in preparation by the Geologic Branch. This list constitutes the source data used in preparation of *Economic Mineral Map No. 5—Manganese* which accompanies this Bulletin 125. It is one of a series of State economic mineral maps (the four previously issued being *Quicksilver*, *Oil and Gas*, *Chromite*, and *Tungsten*) prepared under the direction of the writer.

The base of this map and the others like it is the same as that of the 1938 Geologic Map of California (reduced in scale from 1:500,000 to 1:1,000,000).

An article on the *Utilization of California Manganese Ores* has been prepared for this bulletin by O. Cutler Shepard, Professor of Metallurgy in the Department of Mining Engineering at Stanford University. He describes a recent use of California manganese in the dry-battery industry, which promises to be of postwar importance as well as of critical value during time of war.

A general review of the occurrence of manganese and a description of the principal features of the commercial minerals of manganese have been compiled by Theo H. Crook, who has included a classified selected bibliography pertaining to manganese throughout the world.

The final part of Bulletin 125 is devoted to discussions of the geology and origin of manganese as it is found in the Coast Ranges and Sierra Nevada of California. The first of these papers has been prepared by Nicholas L. Taliaferro of the Department of Geological Sciences, University of California, and Frank S. Hudson, both of whom were engaged during 1917 and 1918 by the Council of Defense to make a field study of the manganese deposits during World War I. The second paper is by Dr. Taliaferro, and comprises a study of the metamorphosed manganese deposits of the Sierra Nevada. These geological discussions have been drawn from many years of detailed field investigations and geological mapping in the northern and central parts of the State.

In order to obviate the possibility of permitting valuable information gathered during this critical war period to be lost in the files during post-war time, the following record is published. The material included in this bulletin has already materially helped in two national war emergencies and will no doubt continue to be of strategic use. Furthermore, utilization of manganese on the Pacific Coast through the development of new industries, such as that of the manufacture of dry batteries, may give to the local industry a permanent life.

OLAF P. JENKINS

October 28, 1943.

# HISTORY OF THE MANGANESE INDUSTRY\*

By ROBERT SCOTT KROGER

## OUTLINE OF REPORT

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## INTRODUCTION

The purpose of this paper is to show the relationship of the manganese industry in California to that of the United States as a whole, and to that of the rest of the world.

The present war is greatly influencing the manganese industry. Russia, the former principal source of manganese, has discontinued shipments. Imports from Africa, India, and South America have increased, but shortage of ships and increased shipping risks have caused a rise in price. Domestic operators, under the stimulus of increased price and demand, have become active to an extent not reached since the first World War. The United States Government is purchasing manganese ore for storing in stock piles as insurance against a dangerous shortage in case all sources of foreign supply are cut off. Government agencies are aiding American operators in the prospecting of deposits and the development of metallurgical processes in hope that domestic mines may be able to produce a substantial part of the manganese required by this country.

Manganese production from California can do little to relieve the gravity of the situation if foreign sources of supply are cut off, but, combined with the production from the rest of the United States, it assumes a position of some importance. Domestic deposits alone, however, probably cannot supply all the manganese ore required by American industry unless tremendous advance is made in manganese metallurgy.

American resources of manganese ore are small when compared with the quantity needed to supply our demands; and measures intended to force American industries to use large amounts of domestic ore in time of peace are basically unsound. Instead of developing an industry that could supply a large part of the ore needed by this country, such measures tend to deplete our few reserves of high-grade ore that could be of greatest value to us in time of national emergency.

In the interest of national economy and security, manganese for American industries, in time of peace, should be obtained from foreign

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\* Abstracted from a portion of the thesis *A Study of the Manganese Resources of California*, by Robert Scott Kroger, submitted in partial fulfillment of the requirements for the degree of Engineer, Department of Mining Engineering, Stanford University. Work was done under the direction of Professor Charles A. Dobbel during 1941. The *Tabulation of Manganese Deposits in California*, prepared by Mr. Kroger for the thesis, formed the basis for the *Tabulated Data on Manganese Properties of California* published in this bulletin. Manuscript prepared for publication September 1943.

deposits. Those deposits in the United States that might suffer irreparable damage by temporary abandonment should receive attention either through Government aid or Government operation; but the vast majority of the manganese deposits of this country are shallow and can be abandoned with little loss. Foreign ore should be purchased by the Government and stored in stock piles, as it is at the present time. These stock piles would serve as a reservoir of ore from which industry can draw, in time of emergency, while domestic deposits are brought into production.

### EARLY HISTORY OF MANGANESE<sup>1</sup>

The earliest known use of manganese was by the ancient Egyptians and Romans who decolorized glass with oxides of the metal. Chemists worked with manganese compounds before 1656, but it was not until 1740 that these compounds were distinguished from those of iron. In that year Potts showed that manganese oxides form a series of salts distinct from those of iron, but manganese was not yet recognized as a separate metal. Scheele was the first to investigate manganese and its compounds systematically. The results of his work, published in 1774, gave the first detailed knowledge of manganese. Although Scheele suspected the existence of a new metal, he was unable to isolate it. This was accomplished for the first time two years later, in 1776, by Gahn. Scheele's work, however, did result in the discovery of chlorine gas,<sup>2</sup> through which, 11 years later, developed the first major market for manganese ore.

Early uses of manganese were limited to decolorizing glass and coloring glass and pottery. The use of chlorine as a bleaching agent began about 1785 and introduced a use for manganese as an oxidizing agent in the production of chlorine. For a number of years this was the principal use of manganese ore, and it has continued to a small extent to the present day. Successful methods of regenerating the manganiferous waste products from the chlorine works, developed about 1855, materially reduced the demand for this purpose.

The value of manganese as a purifier in the smelting of iron and steel was recognized before the end of the eighteenth century, and one patent was granted on this principle in 1799. Other early patents were obtained but it was not until 1839 that manganese began to be used in the manufacture of iron and steel. Josiah Marshall Heath, a resident of Madras, India, was responsible for this step forward in ferrous metallurgy. He obtained steel from low-grade Indian iron ores by adding to the molten iron an alloy which he made by smelting a mixture of coal-tar and manganese oxide. Heath later found that the same effect could be obtained by adding the unsmelted mixture of manganese ore and coal-tar to the steel. His success completely revolutionized the steel industry, but he lost the benefit of his discovery because he failed to patent the use of the mixture.

The introduction, in 1856, of the Bessemer process greatly increased the production of steel and resulted in a substantial increase in the demand for manganese. One drawback of the Bessemer process was that the blast burned all the carbon from the charge, leaving wrought iron

<sup>1</sup> Penrose, R. A. F. Jr., *Manganese: Its uses, ores, and deposits*: Arkansas Geol. Survey Ann. Rept. 1890, vol. 1, 642 pp., 1891.

<sup>2</sup> Harder, E. C., *Manganese deposits of the United States*: U. S. Geol. Survey Bull. 427, p. 243, 1910.



instead of steel. To remedy this, spiegeleisen, an alloy of iron, manganese, and carbon, was added to the furnace at the end of the melt. The carbon in the alloy replaced that burned out by the blast. This alloy was developed by Robert Mushet in 1856, a short time after the Bessemer process was made known.

Because of its relatively high carbon content, spiegeleisen could not be added to certain steels in quantities sufficient to supply the desired manganese without excessively raising the carbon content of the steel. Ferro-manganese, an alloy with a 75 percent manganese content, was developed in 1865 by W. Henderson to meet the requirements for these steels. Ferromanganese is now the principal form in which manganese is added to steel.

High manganese steel, containing at times more than 20 percent manganese, was developed in 1882 by Sir Robert A. Hadfield.<sup>3</sup> Previous to that time it was believed that an excess of manganese caused brittleness in the steel.

More than 90 percent of the manganese used today is consumed by the steel industry, to which it is almost as vital as the iron itself. The amount of manganese required varies with the kind of steel and the process of manufacture, but about 14 pounds of manganese per ton of steel has been the average consumption over a period of years.

## MANGANESE IN THE UNITED STATES

### History

Manganese was first produced in the United States in 1837, in Tennessee,<sup>4</sup> but it was not until 30 years later that any serious mining was attempted. By 1879 there had been a production from Tennessee, Arkansas, Vermont, Virginia, Georgia, and California, totaling more than 40,000 tons.

The first manganese produced was used in the manufacture of chlorine and bromine. The American steel industry drew most of its ore from deposits in other countries, although a portion of the domestic ore did go into the production of spiegeleisen and ferromanganese in this country as early as 1870 and 1874 respectively.

Previous to 1890, the United States held a major place in the world as a manganese-producing nation. Production figures for 1888 and 1895<sup>5</sup> indicate that only Russia had a larger output in those years. Until 1888, a portion of the manganese produced was shipped to England; but in that year home consumption became so large that exportation of ore ceased, and since 1890 the bulk of the ore used in this country has been imported.

A maximum year's production of 34,542 tons of domestic manganese ore was mined in 1887. After this date the industry gradually declined. There were minor fluctuations, with one gain in 1898 during the Spanish-American war, but the decline continued and production reached a minimum of 1,544 tons in 1909. With the outbreak of war in Europe in 1914, manganese ore imports were curtailed and domestic mines again

<sup>3</sup> Harder, E. C., op. cit., p. 244.

<sup>4</sup> J. W. Furness, in *The Manganese Situation from a Domestic Standpoint*, U. S. Bur. Mines Inf. Circ. 6034, 21 pp., 1927, says:

"Mining of manganese in the United States began in 1832 at Paddy Run Mine, Frederick County, Virginia, and during the first few years of operation some 5,000 tons of high-grade ore were shipped to England."

<sup>5</sup> Weeks, Joseph D., *Manganese: Mineral Resources U. S.*, 1889-90, p. 130, 1892.

resumed production. Production climbed rapidly from 2,635 tons in 1914 to an all-time high of 305,869 tons of ore in 1918.

This 1918 production would have supplied our requirements in any year previous to 1912, but it supplied only 35 percent of the ore used in 1918. It was made under the stimulation of a price five times as great as before the war, with modified requirements as to manganese content and impurities of the ore. Nearly half a million tons of high-grade foreign ores were imported to supplement our supply, and to be mixed with low-grade domestic ores in order to allow their use without altering the grade of the steel.

### Economics

Although manganese ore is consumed in the United States at an average yearly rate of nearly 500,000 long tons, the average domestic production is less than 7 percent of that amount. For this reason American industries must depend upon imported ore for more than 93 percent of their requirements. Russia, India, Gold Coast, Brazil, and Cuba are the principal sources of supply, Russia supplying about 40 percent of the total amount in normal times.

In time of peace, most domestic deposits cannot compete with the foreign production that combines the advantages of large orebodies, cheap labor, ore of high manganese content, and low ocean freight rates. Shipping charges are often especially favorable as the ore can serve as ballast in those cases where ballast is needed.

During periods of restricted sea trade, foreign ores cannot be imported as easily as they can under normal conditions. At such times the price of imported ore rises to a level at which domestic ores can be produced profitably, and many American mines which are normally idle are brought into production.

The condition of restricted sea trade during World War I was responsible for the expansion of the American manganese industry from an average production of less than 5,000 tons per year during the period from 1900 to 1914, to a production of more than 300,000 tons in 1918. Despite high price and lowered specifications, however, most of the domestic manganese ore was produced at a loss. The War Minerals Relief Commission examined 461 claims made by manganese operators, and made awards to 239 claimants to compensate them for losses incurred during the war period, as a result of the Government stimulation encouraging investment in manganese property.<sup>6</sup>

After World War I the domestic manganese industry was again faced with the problem of trying to sell ore in competition with cheaper foreign supplies. The price of manganese ore dropped and requirements were raised to prewar levels. Production in the United States dropped to 13,404 tons in 1922, and the American manganese industry was rapidly approaching the conditions existing before the war. On September 22, 1922, American mines were given the protection of a tariff of one cent per pound of manganese content on imported ores containing 30 percent or more manganese, and one and seven-eighths cents per pound of manganese content on imported ferromanganese. This duty was levied in the hope that the United States might be able to develop a manganese indus-

<sup>6</sup> Furness, J. W., Manganese and manganiferous ores in 1925: Mineral Resources U. S., 1925, pt. 1, pp. 174-175, 1927.

try which could supply a substantial portion of the nation's needs, and at the same time develop reserves to be drawn upon in case of a national emergency. Although the production of domestic ore did increase under this tariff, the bulk of the nation's supply of ore was still imported. There were several reasons for this.

The tariff was not high enough to eliminate foreign competition for any but the largest of the American mines; those mines which depended upon the artificially maintained price of manganese ore for their successful operation, were continually faced with the possibility that the duty might be removed. Capital was reluctant to invest in mines which might become valueless at the next session of Congress; and development work was carried on from day to day, rather than with a view to future production.

The situation was made worse by the consumers, who were working to have the duty removed. They claimed that the duty was costing them, and thus the consumers of their products, millions of dollars annually without serving the purpose for which it was intended. They pointed to the fact that domestic production was supplying only a small portion of the nation's needs (14 percent in 1925, but less than 10 percent on an average), even with the protection of the tariff; they further claimed that domestic reserves were inadequate for American self-sufficiency.

Producers, on the other hand, claimed that the duty was not high enough, that the industry had progressed under the protection given it, and that the methods for treating low-grade ore could be put on a commercial basis with the help of an increase in the tariff. They complained that there was no market for the ore which they could produce.

There is truth in the claims on both sides of the question. It can be easily understood why the consumers would buy foreign high-grade ore, with guaranteed shipments of constant quality, in preference to domestic ore from small deposits, with the resulting irregularity of quality and supply. Experiments on beneficiation of low-grade ores by the United States Bureau of Mines, various universities, and companies have developed numerous tentative methods of utilizing the low-grade ores with which we are well supplied; but the problems encountered were often difficult and time was required to solve them. Even with the help of the tariff, most mines cannot produce and concentrate low-grade ore as cheaply as high-grade ore can be supplied by Russia, India, Gold Coast, or Brazil.

In 1930 the tariff was extended to cover ore with from 10 to 30 percent manganese, but whatever effect this may have had upon domestic mining was concealed by the world depression and general decline in all business during the following years.

On January 1, 1936, the duty was reduced to one-half cent per pound of manganese content of ore imported, and to one cent per pound of manganese on imported ferromanganese. The tariff has not been changed since that time.

It is highly desirable to have the United States entirely independent of foreign nations in obtaining its supply of such a necessary material as manganese; but if, in the attempt to attain this independence, the reserves are depleted to such an extent that they will not be available to fall back upon in time of serious need, the cause of national independence has defeated itself.

Harder and Hewett<sup>7</sup> prepared a summary of the manganese deposits of the United States, which is probably the most reliable estimate of the reserves of manganese ore as they existed at the end of World War I. Converting their estimate into metallic manganese, and assuming 75 percent recovery in mining, refining, and smelting, there was a reserve of something over 3,000,000 tons of metallic manganese in the United States in 1919, or enough to supply our needs for approximately 15 years at the average rate of consumption during the 10 years preceding the outbreak of World War II. More than half of this reserve was in the Cuyuna Range in Minnesota, where there are large deposits of ferruginous manganese ores carrying over 5 percent manganese. If in 1922 the tariff had been raised to force domestic steel mills to use manganese ore from American mines, we should have found ourselves today with seriously reduced reserves of high-grade ore and notably lowered reserves of low-grade ore. Our reserves, particularly those of low-grade ore, have been greatly increased and will no doubt be further increased by the discovery of new deposits, the further development of old deposits, and the development of new concentration methods; but our reserves are by no means unlimited.

Although the supply of manganese ore is great enough to carry us through most emergencies, there still remains the problem of mining, concentrating, and shipping this ore on relatively short notice. Mining equipment and milling machinery are costly, and they become useless with the passage of time; therefore, if they are to be installed and ready for use, there must be a market for the material which they are intended to produce. A tariff or subsidy is the means of supplying that market; but it also tends to deplete, rather than conserve, the reserves. The building of stocks for emergency use, as in the present Government program of stock-piling, for example, is one answer to the problem. By maintaining sufficiently large stocks of foreign manganese ore to supply any possible need over a period of several years, and then supplying domestic consumption with foreign ore, our reserves can be left intact, to be used only when foreign ore is not available. The nation's requirements can then be supplied from reserve stocks during the time required to bring domestic deposits into production.

The building of stock piles of strategic minerals by the Government suggests the possibility of a polymetal coinage. It is not inconceivable that future money may be based upon the value of raw materials stored for emergency use; and manganese could well be one of those materials upon which the Government might issue currency as it does upon gold today.

Building stocks of vital materials for emergency use is not a new idea. Stocks of manganese ore have been built in many of the nations of the world. France, in 1923, started importing more manganese ore than was needed for current consumption, and this practice was followed by Germany and other industrial nations in the following years. Roush,<sup>8</sup> through a comparison of imports with probable consumption, has estimated that there was a probable stock of 3,000,000 tons of ore in France and 1,200,000 tons in Germany, by 1940.

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<sup>7</sup> Harder, E. C., and Hewett, D. F., Recent studies of domestic manganese deposits: *Am. Inst. Min. Met. Eng. Trans.*, vol. 63, pp. 3-50, 1920.

<sup>8</sup> Roush, G. A., *Manganese: Mineral Industry*, vol. 49, p. 394, 1941.

A comparison of Russian production and exports indicates that Russia has also built large stocks of manganese ore. Previous to 1933 the excess of production over exports was about equal to the probable Russian consumption; but since that time the ore retained within the country has been far out of proportion to any domestic needs. It is possible, however, that since 1933 Russia has been reporting production in terms of crude ore, while exports are given in terms of the refined product. In this case, the excess production would represent that material lost as tailings in the washing plants, instead of ore in stock piles.

Stocks of manganese ore have been maintained in the United States for many years, at first in quantities sufficient to supply the demand for a short period only, but in recent years in greatly increased quantities. The Government stockpiling program is one of the most recent steps in this direction; but consumers have been maintaining stocks of ore for their own protection, and considerable ore is stored in warehouses where it can remain without duty charges until needed.

The accompanying table<sup>9</sup> shows the trend toward increasing stocks during the past 10 years. It shows that there were nearly 2 million tons of manganese ore available in stocks in the United States in 1940. While large, this is by no means a comforting total, as it would supply American industries for only 18 months at the rate of consumption attained in 1940.

*Stocks of foreign manganese ore in the United States*

Thousands of long tons at end of year

<i>Year</i>	<i>Stocks in Bonded Warehouses</i>	<i>Approximate Consumer Stocks</i>	<i>Approximate Total Stocks</i>
1931-----	613.8	65	679
1932-----	622.5	50	673
1933-----	490.8	89	580
1934-----	430.7	155	586
1935-----	418.3	123	541
1936-----	366.4	325	691
1937-----	681.3	526	1,207
1938-----	842.0	583	1,425
1939-----	903.6	691	1,595
1940-----	913.0	1,074	1,991

**POLITICAL AND COMMERCIAL CONTROL OF WORLD  
MANGANESE SUPPLIES**

Of the manganese produced from 1929 to 1938, more than 87 percent originated under two political units. Russia, through its operation of the deposits of Chiaturi and Nikopol, controlled 49.8 percent of the world's production; while the British Empire, through the production of India, Gold Coast, Union of South Africa, and Egypt, held political control of 37 percent of the world's production. The United States, on the other hand, had only 1.0 percent of the production within her political control.

Commercial control of the world's manganese industries was held mainly by three groups. Russia maintained commercial control over the deposits within her borders, which accounted for 49.8 percent of the total world production. The British Empire held commercial control of 27.3 percent, and the United States controlled 16.3 percent of the world's production. The British Empire controlled operations in India, Union

<sup>9</sup> Roush, G. A., op. cit., p. 404.

of South Africa and Egypt, but operation of the Gold Coast deposit is controlled by American interests under lease from British fee owners. American interests also control operation of the manganese deposits in Brazil and Cuba.

#### MANGANESE IN CALIFORNIA

Manganese was known in California at least as early as 1857, when a vein of ore was discovered<sup>10</sup> near Sonora, Tuolumne County, by Henry S. Macomber.<sup>11</sup> Production of manganese began in 1866, when more than 200 tons of ore was mined on Red Rock Island, a small island about 8 miles north of San Francisco, in San Francisco Bay. This ore was shipped to New York, but it did not bring enough to pay for the freight and commissions, and production stopped.<sup>12</sup>

In 1867 mining was started in San Joaquin County at the Ladd mine, by A. S. Ladd; and between then and 1874 more than 5000 tons was produced. Most of this ore was sent to England for use in the manufacture of chlorine. Because California ore had to be shipped around Cape Horn to reach the points of consumption, transportation costs were so great that it could not be sold in competition with ore from Spain and Brazil, where the deposits were richer than those in California and the distance to England much less than from California.

In 1874 the Ladd mine was sold to Justinian Caire, of San Francisco, and about 1875 shipments to England were discontinued because of the high transportation cost. As some ore was consumed in California, Caire continued operations at the Ladd mine on a small scale, to supply the limited needs of his own chemical works in San Francisco, and to supply the small demand within the State. There was also an early production from Santa Clara County, and a small production in 1882 from a deposit near Sausalito. This ore was used as flux in a local smelter.

Judging from the list of minerals which were exhibited by California at the New Orleans Exposition in 1884<sup>13</sup> manganese was known in at least 12 counties by that time. These counties were: Alameda, Calaveras, Contra Costa, Marin, Mariposa, Napa, Nevada, San Bernardino, San Joaquin, Santa Clara, Sonoma, and Tuolumne. By 1890 manganese was also known to occur in Colusa and Placer Counties.

Production in California reached a maximum of 1,500 tons for the year 1888. This was far above the average annual California production, which fluctuated from nothing to 880 tons per year, and averaged only 274 tons per year during the following 26 years. Interest in manganese seemed to be slight; and Penrose<sup>14</sup> said of his work on the subject in California about 1890:

"In fact, the work that was once done has been almost entirely forgotten, the subject excites no general interest, and information concerning the different localities and their history is difficult to obtain."

As late as 1914, only 45 prospects from 25 counties had been mentioned in various publications, and there had been production from only 13 of the prospects.

At the opening of World War I, California mines joined those of the rest of the nation in a sudden increase in activity. From no production

<sup>10</sup> Pedro deposit; see tabulated list, Tuolumne County, sec. 25, T. 2 N., R. 14 E., M. D.

<sup>11</sup> Hanks, H. G., Manganese ores shown at New Orleans Exposition: California Min. Bur. Rept. 5, p. 106, 1884.

<sup>12</sup> Day, David T., Manganese: Mineral Resources U. S., pp. 424-425, 1882.

<sup>13</sup> Hanks, H. G., op. cit., p. 106.

<sup>14</sup> Penrose, R. A. F., Jr., op. cit., p. 480.

in 1913 and only 501 tons in 1914, production climbed to 24,067 tons in 1918. More than 300 new prospects were opened and 102 properties, 97 of them new discoveries, were producing ore by the end of 1918. Much of the ore produced would not have met peace-time specifications; and most of it was produced at a loss, even under war-time prices. The War Minerals Relief Commission received 88 claims and made 34 awards, totaling \$156,757.95, to California producers to compensate them for losses incurred during the war.

After the war, when prices and specifications were again at peace-time levels, California mines returned to their unproductive condition. Interest in manganese was slight; only 21 new prospects were opened between 1920 and 1939, and only 13 mines produced ore during that period. A production of 11,289 tons was made in 1919 because of held-over wartime contracts; but from 1920 to 1939 only 5,696 tons was produced, 1,733 tons of it in 1920.

The opening of World War II brought a revival of interest in California manganese deposits. Many of the old claims have been relocated; ore buyers are again in the market for domestic ores; the United States Bureau of Mines and United States Geological Survey are making surveys, diamond drilling, and conducting research on metallurgical recovery.





# OCCURRENCE AND MINERALS OF MANGANESE

By THEO H. CROOK\*

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## OCCURRENCE OF THE ELEMENT MANGANESE

The element manganese has at least five valences, making possible numerous compounds. Its behavior, chemically and geologically, more nearly parallels that of iron (with which it frequently occurs) than of any other element. The metal oxidizes readily, and consequently is never found uncombined in nature.

In abundance manganese ranks twelfth among the elements in the outer 10 miles of the earth's crust, and is calculated to form 0.09 percent

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of it. Iron ranks fourth and is approximately 56 times as abundant as manganese.

Igneous rocks and solutions of magmatic origin are the original sources of manganese. Numerous analyses of igneous rocks indicate the general average manganese content to be about 0.1 percent. Certain basic igneous rocks may contain as much as 0.36 percent; but in such form the manganese is not economically recoverable. Manganese also occurs in other types of rocks, as well as in most organic substances, in underground waters and springs, in streams, lakes, and the oceans, and in recent lake and deep-sea deposits.

Economically important concentrations of manganese are found upon every continent; and most of the world's valuable deposits occur in or closely associated with strata of sedimentary origin.

### THE MANGANESE MINERALS

Harder (4)<sup>1</sup> lists more than 100 minerals containing manganese. Of these, 29 are oxides, 4 are carbonates, 44 are silicates, and the remainder miscellaneous. More recent work has added to the number of known manganese-bearing minerals.

Practically all of the world's production of manganese comes from the oxides. Of the carbonates, only rhodochrosite, when found in workable quantity, has been used as an ore. The silicates rhodonite and bementite occur in workable deposits, but cannot be utilized economically at present.

#### The Manganese Oxides

Of the common manganese oxides, manganite, hausmannite, braunite, and pyrolusite in some of its habits, are usually identifiable by ordinary field and laboratory methods. Such methods, however, have proven inadequate to distinguish some of the common oxides which have frequently been classified under the general descriptive terms "psilomelane" and "wad".

"Psilomelane" has often been used to refer to any hard, compact manganese oxide too fine-grained to be determined accurately by ordinary methods, and consequently included a group of substances with more or less similar physical properties. It could not be assigned a satisfactory chemical formula because of the variability in the chemical composition of those substances. Likewise, the term "wad" has been generally applied to soft material of low apparent specific gravity. The resulting unsatisfactory state of nomenclature has been recognized for some time.

Fleischer and Richmond, in the Chemical Laboratory of the United States Geological Survey, have undertaken intensive studies of the manganese oxide minerals, including studies of X-ray powder photographs, chemical compositions, physical and optical properties, and the behavior of the oxides when heated. A preliminary progress report has been published (115) summarizing the results obtained so far. This timely paper has been drawn upon exclusively for the data here presented. For additional information the reader is referred to the paper itself.

Concerning the identification of the oxide minerals, Fleischer and Richmond remark:

"It is evident that identifications based on physical properties are highly uncertain, owing to the variability of these properties and their overlapping. Hardness is a particularly poor criterion. The streak may be helpful, but must be used with caution. . . . it may be said that identification of well-crystallized material is possible, but that identification of fine-grained material is as yet uncertain."

<sup>1</sup> Numbered references refer to the bibliography at the end of this paper.

They also point out that X-ray powder pictures are the only certain means of identifying many samples, and for some minerals these must be supplemented by qualitative chemical tests.

"Optical study by reflected light has as yet proved to be of less value, chiefly because many samples are so fine-grained that they are apparently isotropic, hence are indistinguishable when examined by reflected light. Such samples have commonly been reported in the literature as amorphous. X-ray study shows that nearly all of these apparently isotropic specimens are crystalline."

They believe that it is desirable to reserve the term "psilomelane" for one of the distinct oxide minerals—as hereinafter described. Furthermore, in recognizing that field difficulties in the identification of some of the oxides may require the convenience of some collective term, they recommend the following:

"(1) Massive, hard, heavy material not specifically identified should be referred to as belonging to the '*psilomelane type*.' This term is to be understood to include several distinct minerals or mixtures of them, and no chemical formula should be given.

"(2) Massive, soft material of low apparent specific gravity, not examined in the laboratory, should be referred to as '*wad*.' Such material also may be any one of several distinct minerals, may be a mixture, or may be unidentifiable and no chemical formula should be given.

"(3) Definitely identified minerals should be named as listed below."

Concerning the mineralogy of the manganese oxides, Fleiseher and Richmond state:

"The following list includes all the recognized manganese oxide minerals with the exception of a few very rare species and some of doubtful validity. The formulas marked (?) are new and subject to revision. The four minerals marked with asterisks are by far the most common, judging by the specimens studied in this laboratory.

Bixbyite	(Mn,Fe) <sub>2</sub> O <sub>3</sub> .
*Braunite	3(Mn,Fe) <sub>2</sub> O <sub>3</sub> .MnSiO <sub>3</sub> .
Cesarolite	PbMn <sub>3</sub> O <sub>7</sub> .H <sub>2</sub> O. Rare.
Chalcophanite	(Mn,Zn)Mn <sub>2</sub> O <sub>5</sub> .2H <sub>2</sub> O. Rare.
Coronadite	PbR <sub>2</sub> O <sub>16</sub> (?), R=Mn <sup>IV</sup> chiefly, also Mn <sup>II</sup> ,Cu,Zn.
Crednerite	CuMn <sub>2</sub> O <sub>4</sub> . Rare.
*Cryptomelane	KR <sub>2</sub> O <sub>16</sub> (?), R=Mn <sup>IV</sup> chiefly, also Mn <sup>II</sup> ,Zn,Co.
Galaxite	(Mn <sup>II</sup> ,Fe <sup>II</sup> )(Al,Fe <sup>III</sup> ) <sub>2</sub> O <sub>4</sub> . Rare.
Hausmannite	MnMn <sub>2</sub> O <sub>4</sub> .
Hetaerolite	ZnMn <sub>2</sub> O <sub>4</sub> .
Hollandite	BaR <sub>2</sub> O <sub>16</sub> (?), R=Mn <sup>IV</sup> chiefly, also Fe <sup>III</sup> ,Mn <sup>II</sup> ,Co.
Jacobsite	(Mn <sup>II</sup> ,Fe <sup>II</sup> ,Mg)(Mn <sup>III</sup> ,Fe <sup>III</sup> ) <sub>2</sub> O <sub>4</sub> .
Lithiophorite	Li <sub>2</sub> (Mn <sup>II</sup> ,Co,Ni) <sub>2</sub> Al <sub>2</sub> Mn <sup>IV</sup> <sub>10</sub> O <sub>35</sub> .14H <sub>2</sub> O(?).
Manganite	MnO(OH)=Mn <sub>2</sub> O <sub>3</sub> .H <sub>2</sub> O.
Manganosite	MnO. Rare.
Polianite	=Pyrolusite. The name polianite should be dropped.
*Psilomelane	BaR <sub>2</sub> O <sub>16</sub> .2H <sub>2</sub> O(?), R=Mn <sup>IV</sup> chiefly, also Mn <sup>II</sup> ,Co.
Pyrochroite	Mn(OH) <sub>2</sub> . Rare.
*Pyrolusite	MnO <sub>2</sub> .
Quenselite	Pb <sub>2</sub> Mn <sub>2</sub> O <sub>5</sub> .H <sub>2</sub> O. Rare.
Ramsdellite	MnO <sub>2</sub> (dimorph of pyrolusite).
Ranciéite	(Ca,Mn <sup>II</sup> )Mn <sup>IV</sup> <sub>2</sub> O <sub>6</sub> .3H <sub>2</sub> O(?).
Sitaparite	=Bixbyite. The name sitaparite should be dropped."

The following descriptions of some of the more common oxides are extracted from those published by Fleiseher and Richmond.

"*Pyrolusite*—MnO<sub>2</sub>, commonly with a little nonessential water. Tetragonal. Color iron-gray to black. Streak dead black. Hardness nearly always 2-2½, but in some specimens higher, up to 6½. Sp. gr. 4.9-5.0 pure, 4.7-4.8 for most specimens. The commonest manganese oxide mineral, occurring in several habits:

- (1) Compact, fine-grained, dense masses with a tendency to fracture conchoidally.
- (2) Massive, friable, with grain size usually somewhat larger than the compact variety. Easily broken down with the fingers.
- (3) Botryoidal, occurring in radiating crystals or crystallized masses with an external form resembling clusters of grapes, which may be large or small. There may be several composite bands making up each 'grape.' In many of the finely banded specimens composed of harder and softer bands, the softer portion is pyrolusite and the harder portion may be pyrolusite, cryptomelane, or psilomelane.
- (4) Crystals, commonly as pseudomorphs after manganite; in long, prismatic crystals which may have several terminal forms, or may have only the base, or may taper to a sharp wedge. Good tetragonal crystals with well-developed terminal forms are known only from Platten, Bohemia ('polianite').

"*Cryptomelane*—KR<sub>2</sub>O<sub>16</sub>(?), R=Mn<sup>IV</sup> chiefly, also Mn<sup>II</sup>,Zn,Co. Most samples contain 2-4 per cent non-essential water. Most of the analyses correspond fairly well to this formula, but some differ considerably from it. A satisfactory explanation for these discrepancies has not yet been found. Tetragonal. Color steel-gray to black, tarnishes black. Streak dark brownish-black. Hardness most commonly 6-6½, but the apparent hardness of cleavable and fibrous varieties may be as low as 1. Sp. gr. approximately 4.3.

"Cryptomelane is probably the commonest of these minerals excepting pyrolusite. It occurs in a number of habits:

- (1) Most commonly as very fine-grained steel-gray dense compact masses showing marked conchoidal fracture.
- (2) Less commonly as botryoidal masses.
- (3) Uncommonly as coarse cleavage masses that would not ordinarily be labelled 'psilomelane type'. This variety has an apparent hardness of 3-4. Known only from Romanèche, France, where the crystals occur on massive psilomelane. Specimens from Tombstone, Arizona, and Lake Valley, New Mexico, show filament-like fibers of cryptomelane. Similar material from Nassau, Germany, has been described by Ramsdell.

"Cryptomelane was first distinguished as a distinct mineral species by Ramsdell (122), who referred to it as 'true psilomelane'. The name cryptomelane was recently proposed by us (124).

"*Psilomelane*— $\text{BaR}_3\text{O}_{18} \cdot 2\text{H}_2\text{O}$  (?),  $\text{R}=\text{Mn}^{\text{IV}}$  chiefly, also  $\text{Mn}^{\text{II}}, \text{Co}$ . The water is essential (difference from hollandite, whose composition is very similar). Orthorhombic. Color and streak black. Hardness usually 6, but in some specimens the apparent hardness is lower, down to 2. Sp. gr. 4.4-4.7. A common mineral; only pyrolusite and cryptomelane are encountered more frequently. Most commonly in botryoidal masses, which in some instances consist of concentric layers. The layers may be psilomelane, psilomelane and pyrolusite, or psilomelane and cryptomelane. Also occurs in irregular or cellular masses, and rarely as long prismatic crystals (pseudomorphs ?) resembling a common variety of pyrolusite.

"*Manganite*— $\text{MnO}(\text{OH})$ . Monoclinic; pseudo-orthorhombic. Color dark steel-gray to iron-black. Streak chocolate-brown. Hardness 4. Sp. gr. 4.3. Occurs in prismatic crystals. Commonly partly altered to pyrolusite.\*

"*Hausmannite*— $\text{MnMn}_2\text{O}_4$ . Tetragonal. Color brownish black to reddish. Streak reddish-brown. Hardness 5-5½. Sp. gr. 4.9. Occurs in well developed crystals resembling octahedrons, and in granular masses. Commonly twinned.

"*Braunite*— $3(\text{Mn}, \text{Fe})_2\text{O}_3 \cdot \text{MnSiO}_3$ . Tetragonal. Color and streak dark brownish-black. Hardness 6-6½. Sp. gr. 4.8. Occurs in well developed crystals resembling octahedrons and in compact granular masses. Common in the United States. Decomposed by HCl, leaving a residue of gelatinous silica.\*\*

#### Other Manganese Minerals

Descriptions of the non-oxide manganese minerals are here limited to those of most important occurrence in the Pacific Coast area: rhodochrosite, rhodonite, and bementite.

*Rhodochrosite* (129)— $\text{MnCO}_3$ . Hexagonal. Perfect rhombohedral cleavage; fracture uneven. Hardness 3.5-4.5. Sp. gr. 3.70 (when pure) but ranging from 3.1-3.7 in rhodochrosite containing variable amounts of  $\text{FeCO}_3$ ,  $\text{MgCO}_3$ , and  $\text{CaCO}_3$ , one or more of which are generally present in completely miscible isomorphous form. Color usually rose-red or pink when pure; also gray, reddish-gray, brownish red, and more rarely, colorless. Luster vitreous to pearly. Streak white, or nearly so. Effervesces slightly with acid.

Crystals are rhombohedral in habit, usually small and rare. Occurs generally in cleavable, dense, tough granular and botryoidal masses; also in crusts; occasionally colloform. Rhodochrosite is generally found in its purest form in vein deposits; in bedded deposits it is generally impure.

*Rhodonite*— $\text{MnSiO}_3$ . Usually contains some  $\text{FeSiO}_3$  or  $(\text{Ca}, \text{Mg})\text{SiO}_3$ , or both. Triclinic. Perfect prismatic and basal cleavages. Fracture conchoidal to uneven. Hardness 5.5-6.5. Sp. gr. 3.4-3.7. Color rose-red, pink, gray, or yellowish; brown to black by alteration. Luster vitreous to pearly. Transparent to translucent. Fuses easily to a brown or black glass. Insoluble in hydrochloric acid.

Crystals are usually tabular or prismatic, comparatively large, are often rough with rounded edges, but not very common. Generally occurs in fine-grained, cleavable, or compact masses; also in disseminated grains.

*Bementite*— $8\text{MnO} \cdot 5\text{H}_2\text{O} \cdot 0.7\text{SiO}_2$  (121), a hydrous silicate of manganese. Orthorhombic.

According to Pardee, et al. (121), in western Washington, where bementite is a common mineral in the manganese deposits of the Olympic

\* Cleavage: (010) very perfect, (110) perfect.

\*\* Cleavage: (111) perfect.

Mountains, the fresh material is light gray or grayish-brown in color, has a vitreous luster, is transparent in splinters, but upon weathering the color darkens and the material becomes dull and opaque, even in splinters. Hardness about 6. Sp. gr. 3.11. Tough, and has a splintery fracture. Is decomposed by hot acid and fuses easily to a black glass. Most of the material is very finely crystalline.

According to Trask, Wilson, and Simons<sup>2</sup> the bementite which is found at many places in California varies in color from dark honey-yellow or reddish-brown to straw color, is generally finely crystalline, and has a highly characteristic waxy luster.

Miser and Hewett (31) note the presence of bementite in the manganese deposits of Batesville, Arkansas, as generally forming

" . . . pale-brown veinlike irregular masses that break with a conchoidal fracture and do not reveal the fact that they are made up of myriads of minute interlocking micaceous plates . . . In a few places . . . bementite forms clusters of spherical aggregates of radiating micaceous gray plates . . ."

### CLASSIFICATION OF MANGANESE DEPOSITS\*

The classification of ore deposits in general is treated at length by Lindgren (6) and Bateman (1). Bateman, in his chapter *Classification of Mineral Deposits*, gives a review and discussion of the various schemes hitherto offered, and proposes a new classification. However, as he points out, none can be simple and concise in form and terminology and yet provide pigeon-holes for some deposits formed by the operation of more than one process of mineralization or concentration, or for deposits formed by processes difficult to distinguish or even to determine. Bateman's comment is especially applicable to manganese deposits, and the variety of classifications presented in the literature affords ample substantiation.

Some manganese deposits are relatively simple and there is little question as to their origin; such deposits are readily classified. Some deposits, especially those in ancient rocks, are extremely complex, largely because they have been subjected to various processes, and are not so readily classified. In some instances deep oxidation has so profoundly altered the ores that their original nature may be obscure. Generally, in cases of multiple processes of manganese mineralization or concentration, deposits are classified according to the dominant process, when this is recognizable.

Geological classifications of manganese deposits have been of two principal types: according to the forms of the occurrences, useful for including those in which the evidence concerning their genesis may be obscure but where their forms and general characteristics are immediately evident; and according to their modes of origin. Examples are:

(1)—*Classification of manganese deposits, based upon form of occurrence*<sup>3</sup>

1. Stratiform masses:

- a. Oxides interlayered with sediments or layered volcanic or metamorphic rocks.
- b. Carbonates or silicates interlayered with sediments or layered volcanic or metamorphic rocks.
- c. Oxides, as surface bog deposits.

\* Grateful acknowledgment is made to Prof. N. L. Taliaferro for helpful suggestions, especially concerning the geological occurrence of manganese.

<sup>2</sup> See *Manganese Deposits of California—A Summary Report*, this bulletin.

<sup>3</sup> Hewett, D. F., Manganese and manganese ores: Mineral Resources U. S., 1918, pt. 1, p. 641, 1921. This classification was used to indicate, on maps of the United States, the forms, with some indications of the modes of origin, of the manganese deposits.

2. Veins and breccia filling :
  - a. Oxides in larger part.
  - b. Carbonates or silicates partly weathered to oxides.
3. Irregular masses :
  - a. Oxides.
  - b. Carbonates or silicates largely weathered to oxides.
4. Aggregates of small oxides in clay or weathered rocks :
  - a. Mainly oxides.
5. Unclassified deposits.

(2)—*Classification of manganese deposits, based upon mode of origin* <sup>4</sup>

1. Hydrothermal deposits :
 

Butte and Philipsburg, Montana ; Leadville, Colorado.
2. Sedimentary deposits :
 

Tchiaturi and Nikopol, Russia.
3. Residual concentrations :
 

India, Cuba, Gold Coast, Brazil, Egypt, Morocco.
4. Metamorphosed deposits :
 

Postmasburg, South Africa ; India ; Olympic Mountains, Washington.

### GEOLOGICAL OCCURRENCE OF MANGANESE

Research in recent years strongly suggests that the principal valuable deposits of manganese now existing have been derived from deep-seated sources during periods of igneous activity, and have been deposited as "original material," whether in disseminated or concentrated form, through the operation of various mineral-forming or depositional processes. These deposits may be in their original state, or may have been subjected to processes of alteration, distribution, concentration, and oxidation.

Sedimentary, residual, and residual-replacement deposits comprise the world's major sources of manganese ore.

#### Sedimentary Deposits

Manganese, derived from disseminated manganese-bearing minerals in the rocks and from former sedimentary and other types of bed-rock deposits, is dissolved during weathering by cold surface waters, transported (some possibly as oxide in suspension, but the greater part probably in aqueous solution), and precipitated in bogs, lakes, or seas as carbonates, under reducing conditions (that is, in the absence of air and in the presence of excess carbon dioxide) ; as oxides, under oxidizing conditions ; or as mixed carbonates and oxides, under conditions not clearly understood.

Manganese derived from waters of deep-seated origin given off during periods of igneous activity, or possibly from the leaching of hot lavas reaching bodies of surface water, is contributed, often in concentrated siliceous colloidal solution, to surface waters, and is precipitated in lakes and seas probably as carbonates, under reducing conditions ; as oxides, under strongly oxidizing conditions ; as manganiferous opal (impure amorphous manganese-silica compound), under conditions not clearly understood ; as manganese silicates, under conditions allowing crystallization of the manganese-silica compound ; and possibly as mixtures of some of the above.

In sediments where manganese derived principally from manganese-rich solutions of magmatic origin is deposited near the subaqueous crustal exits, appreciable concentrations may be found. When manganese from

<sup>4</sup> See Bateman, A. M. (1).



the same source serves only to increase the average manganese content of the waters of the general basin of deposition, it may be deposited as a disseminated constituent of the sediments, probably giving rise ultimately to the widespread manganiferous oolites and concretions found in some sediments.

There is evidence to indicate that manganiferous opal and manganese carbonate are syngenetic constituents of some deposits where the manganese has been contributed from deep-seated sources, but in many such deposits the working of later processes prevents recognition of the original minerals, and the extent to which other manganese-bearing minerals may be syngenetic is not yet clear.

Manganese in some deposits may have been derived from both surficial and deep-seated sources. Deposits containing manganese in the form of concretions, believed to have grown in place by accretion of the disseminated manganese after deposition of the sediments, are here classified as sedimentary.

Sedimentary manganese is stratiform, in beds or lenses parallel to the bedding of the containing sediments; or as concretions distributed parallel to the bedding within limited vertical ranges.

Most of the commercial ores are oxides, either syngenetic in origin, or as commonly the case, secondary alteration products of primary minerals. Reduction of carbonate ores by calcination has recently increased the importance of good workable deposits of carbonates, but as yet such deposits do not furnish any considerable percentage of world manganese production and are generally considered as emergency sources only.

*Examples of oxide deposits:* (1) In formations of Eocene age in the Tsehiaturi District, Georgia, Russia; (2) in the Oligocene of the Nikopol District, Ukraine, Russia; these two districts in Russia accounted for about 45 percent of the world's production of high-grade manganese ore from 1936 to 1938, inclusive; (3) in the Eocene of Oriente Province, Cuba; (4) in the middle Tertiary beds of the Artillery Peak and Topoek areas, Arizona; (5) in the Pliocene on the Island of Milos, Greece; (6) in the Pliocene near Las Vegas, Nevada; and (7) in the Pleistocene near Cleveland, Idaho. It seems probable that waters of magmatic origin furnished the manganese at the localities in Arizona, Idaho, and Nevada.

*Examples of carbonate deposits:* (1) In formations of pre-Cambrian age in the Cuyuna Range, Minnesota (iron and manganese possibly from magmatic sources); (2) in the Cambrian at Trinity and Conception Bays, Newfoundland; (3) in the Cambrian at Merionethshire, Wales; (4) in the Cambrian at Chevron, Belgium; (5) in the Ordovician of the Batesville, Arkansas, area; (6) in the Jurassic of California (manganese probably from magmatic sources); and (7) in the Cretaceous over a large area near Chamberlain, South Dakota.

#### Residual and Surficial Replacement Deposits

Residual and surficial replacement deposits, developed within the zone of weathering and of circulation of meteoric waters, are distinct types and easily distinguishable. Many manganese occurrences, however, including some important ones, show evidence of having been formed by a combination of the processes of residual concentration and replacement of the host rock.

Residual concentration, in the strict sense of the term, results in local accumulation of the relatively stable constituents of rocks, or of new persistent minerals formed in the weathering process, after the less stable constituents have been broken down, dissolved, and carried away in solution. This process is common under conditions favoring chemical decay, and where the residues are not removed by erosion.

In many so-called residual deposits, however, the formation of the manganese ores is accompanied by much low-temperature solution and redeposition of the manganese compounds, probably as precipitates of colloidal mixtures, sometimes giving rise to intimate association of several minerals. Redeposition of the manganese may take place on the surface, in open spaces, or by replacement of other minerals, forming deposits that are neither truly residual nor truly replacement, but which show some of the characteristics of both types.

Manganese deposits of these types are surficial oxide deposits that do not extend to any great depth; they result from the weathering of manganese-bearing minerals of schists, pegmatites, and sedimentary beds—especially the manganese-rich limestones, fissure veins, and other kinds of pre-existing deposits.

The forms of these residual deposits and replacement deposits are variable, often irregular, conforming to the surfaces upon which, or the spaces in which, the manganese is deposited or concentrated. Residual deposits may exist also as irregular masses imbedded in residual clays.

Deposits of residual-replacement type have been thoroughly investigated by Fermor (104, 105). They are among the common and important sources of ore in India.

India, the Gold Coast of Africa, Brazil, Egypt, Cuba, and Morocco provide examples of the more important residual deposits of manganese oxide ores. Those of India, the Gold Coast, and Brazil are considered to have been derived from manganese-bearing minerals in ancient crystalline schists. In the United States, minor residual deposits are found as disseminated and pockety ores in the deep residual clays overlying the Shady limestone (Cambrian) in parts of the Appalachian belt through Virginia, Tennessee, Georgia, and Alabama. Also, near Batesville, Arkansas, ores ranging from 25 to 50 percent manganese occur as “buttons” in the Cason shale (Ordovician) and as irregular masses of oxides in the residual clays that occupy solution depressions in the underlying limestones. Examples are also found in the concentrated bodies of manganese oxides in the oxidized outcrops of the manganese carbonate and silicate bearing veins and lodes of the Butte and Philipsburg districts, Montana.

#### Mechanical Concentrations

Some concentrations of manganese oxides occur in stream gravels and alluvial cones, generally near the larger source deposits, and are worked, if at all, in conjunction with the latter—as in the Batesville area, Arkansas. Such deposits may be stratiform, lenticular, or irregular. Some manganiferous muds may be the result of mechanical concentration of manganese, but they are of no economic importance.

#### Hydrothermal Deposits

There are certain types of manganese occurrences where the manganese, derived from ascending hot solutions, forms replacements, or

open-space fillings such as fissure veins, breccia fillings, solution-cavity fillings, and pore-space fillings. Western United States provides numerous examples of such deposits, where mineralization appears to be genetically associated with igneous activity. Hewett and Pardee (16) describe and discuss these occurrences, including the rhodochrosite and rhodonite veins near Butte and Philipsburg, Montana, from which a large proportion of our domestic production of "battery grade" and "metallurgical grade" ores has been derived. Recent investigations and development projects indicate that our production from such deposits will be considerably increased in the near future.

### Metamorphosed Deposits

Any of the above types of manganese deposits may have suffered further changes as the result of metamorphic processes involving the agencies of heat, pressure, and water. When these processes operate without the introduction of new mineral elements into the rock, two types of metamorphism may be recognized: (1) regional or dynamic; and (2) normal contact metamorphism.

Each type of metamorphism has varying effects upon the pre-existing manganese deposits and the enclosing rocks according to the intensity. In the case of normal contact metamorphism the changes are most pronounced near the borders of the intrusive igneous masses responsible for the contact action. Contact metamorphism of manganese carbonate deposits is analogous to that of limestone. If pure, the manganese carbonate simply recrystallizes to rhodochrosite; if impure, the nature of the impurities governs the minerals formed. Siliceous manganese carbonate deposits subjected to strong contact metamorphism develop, in addition to rhodochrosite, the manganese silicate rhodonite, and the manganese garnet, spessartite. A large number of minerals may be developed by contact action by combination of the manganese with various impurities. Such contact-metamorphosed deposits may, as the result of oxidation at the surface, yield commercial ores. Bodies of unoxidized rhodochrosite, if of sufficient size and purity, may also be of economic importance.

When the manganese minerals are disseminated in crystalline schists, limestones, and dolomites, they are important only as the source of the manganese in locally derived residual or surficial replacement deposits.

Metamorphosed deposits may be classified as "metamorphosed sedimentary," "metamorphosed residual," etc., when the nature of the original deposit is ascertainable; or simply as "metamorphosed" if the origin is indeterminable.

Good examples of metamorphosed deposits are found in California, Oregon, and Washington; also in the Gold Coast of Africa (94a), and in India (92, 104, 105).

### Unclassified Deposits

There are two mineral deposits, at Franklin Furnace, New Jersey, and Langban, Sweden, which are world famous, principally for the large number and variety of manganese minerals present. At Franklin Furnace, zinc is the principal product exploited, and manganimiferous zinc residue is an important by-product used in making spiegeleisen.

Bateman considers this occurrence to be an example of high-temperature replacement, in a region of pre-Cambrian granitic gneisses and crystalline marble cut by pegmatite dikes. Apparently the evidence is obscure as to whether the source of the manganese was the invaded rock, the magma, or both. Lindgren considers that the Langban deposit, in some respects, forms a close analogy to Franklin Furnace, and states:

"It is held that a primary Fe-Mn ore, probably sedimentary, was exposed to granitic intrusions which gave rise to the extremely complicated mineralogical development."

Deposits such as these, regarding whose origin there has been considerable controversy, may well be ancient sediments or residual deposits that have suffered severe contact metamorphism.

#### WORLD SOURCES OF MANGANESE ORE

The world's known major deposits of high-grade ore are limited to the countries shown in the accompanying table. Wartime production (figures largely unpublished) has undoubtedly reached a higher annual average than is shown for the 1936-1938 period. United States wartime production of high-grade manganese is greater than the average shown, and includes considerable and increasing production from large hitherto undeveloped low-grade deposits.

#### PRODUCTION OF MANGANESE ORE IN THE UNITED STATES

Manganese ores are extremely variable in composition and the commercial grades have been classified as follows by the United States Bureau of Mines <sup>5</sup>:

<sup>5</sup> Ridgway, Robert, Manganese—general information: U. S. Bur. Mines Inf. Circ. 6729, p. 1, 1933.

*World sources of manganese ore*

Country	Percent manganese	Average annual production, 1936-1938, inclusive (metric tons)	Percent world production	1940 production
U. S. S. R.	41-48 +	2,675,600	49.18	
British India	47-52	959,500	17.63	
Union of South Africa	30-51	480,392	8.82	412,071
Gold Coast, Africa (exports)	50 +	427,509	7.87	
Brazil	38-50	210,608	3.88	
Egypt	30 +	157,835	2.90	
Cuba	36-50 +	101,205	1.86	119,852
United States, continental (shipments)	35 +	33,083	0.64	40,767
Puerto Rico	48-51	2,156		
All others*	30 +	±393,000	7.22	
Totals		±5,441,000	100.00	

*Metallurgical-grade ores*

- (a) Manganese ores containing 35 percent or more of manganese, used in the manufacture of iron and steel.
- (b) Ferruginous manganese ore containing 10 percent to 35 percent of manganese.
- (c) Manganiferous iron ore containing 5 percent to 10 percent of manganese.
- (d) Manganiferous zinc residuum [a by-product, containing 12 percent to 14 percent manganese, resulting from the roasting of franklinite concentrates at Franklin Furnace, N. J.].

*Battery ores*

[High-grade manganese dioxide is required, low in iron, and free or very nearly free from any metals which are electro-negative, such as copper, nickel, and cobalt. Some concentrated domestic ores are being used].

*\* Other countries*

(including those where manganese is being or has been produced, and those in which deposits are known to exist)

Based on 1936-1938 production average:

General area	50,000-100,000 tons	20,000-50,000 tons	5,000-20,000 tons	1,000-5,000 tons	0-1,000 tons
North America				Mexico	{ Canada Costa Rica Newfoundland Panama
South America					{ Argentina Bolivia Chile Ecuador Peru Uruguay
Europe		{ Hungary Italy Rumania	{ Greece Sweden	{ Bulgaria Yugoslavia	{ Belgium France Germany Great Britain Portugal Spain Switzerland
Asia	Japan	{ China Philippine Islands Unfederated Malay States	{ Portuguese India Netherlands Indies	{ Indo-china Turkey	{ Timor
Africa	{ French Morocco		{ Belgian Congo	{ Northern Rhodesia	{ Algeria Spanish Morocco Tunisia
Oceania					{ New South Wales New Zealand Queensland South Australia Western Australia

Tables based on data from Minerals Yearbook.

*Fluxing ores*

Ores that may contain a few ounces of silver and are rich enough in manganese to make them valuable chiefly for fluxing purpose in non-ferrous smelters.

*Miscellaneous ores*

Ores shipped to brick manufacturers, glass makers, and manufacturers of manganese chemicals [ores containing about 85 percent  $MnO_2$  and not more than 1 percent iron are used by chemical, pottery, and glass industries].

Under war conditions some domestic low-grade ores are utilized and mechanically or chemically concentrated to reach the grades required for metallurgical and battery grade ores.

The lower-grade ores have come into consideration only since 1914. Two types of concentration received most attention—hydrometallurgical processes to produce a concentrate which could be smelted like the higher-grade ore, and processes involving concentration of the manganese from manganiferous iron ores by preferential reduction of iron. According to the United States Bureau of Mines:<sup>6</sup>

"From a hydrometallurgical standpoint manganese ores may be divided into several types; (1) Ores in which the manganese mineral is readily soluble in at least one solvent; (2) ores in which the manganese mineral requires preliminary treatment to make it soluble; (3) ores containing manganese in insoluble form; (4) ores which destroy excessive amounts of solvents due to soluble impurities; (5) ores which present physical properties that increase the cost of treatment.

"In class 1 belong all the higher oxides of manganese, such as pyrolusite, braunite and wad. These minerals are readily soluble in acids but require a reducing roast to prepare them for ammonia leaching. In class 2 belongs rhodochrosite, which requires roasting to expel carbon dioxide before the manganese is readily soluble in sulphurous acid or ammonia. To class 3 belong rhodonite and the partly oxidized black silicate, which are practically insoluble in the usual leaching circuits. Class 4 is represented by ores with high-lime gangue, which precludes acid leaching and favors an alkaline circuit. In class 5 fall ores that contain clay or talc, are more difficult to leach, and are usually benefited by roasting."

Much more detailed information concerning the occurrence, production, milling, metallurgy, and uses of manganese may be found in U. S. Bureau of Mines Information Circulars 6729, and 6768-6772.

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<sup>6</sup> Leaver, E. S., *Hydrometallurgy of manganese*: U. S. Bur. Mines Inf. Circ. 6770, pp. 167-168, 1934.

<sup>7</sup> Containing references selected from a comprehensive bibliography prepared by the writer for Prof. N. L. Taliaferro, Department of Geological Sciences, University of California.



United States production of manganese ores, shipments, long tons\*\*

State	Metallurgical manganese ore (35+ $\%$ Mn)				Ferruginous manganese ore (10-35 $\%$ Mn)				Manganiferous iron ore (5-10 $\%$ Mn)				Battery grade ores				Manganiferous zinc residuum (12-15 $\%$ Mn, 40 $\%$ iron)				Miscellaneous manganese ores		
	1918 (high year, World War I)	1936-1940		1940	1918 (high year, World War I)	1936-1940		1940	1918 (high year, World War I)	1936-1940		1940	1918 (high year, World War I)	1936-1940		1940	1918 (high year, World War I)	1936-1940		1940	1936-1940		1940
		Total production	Average annual production			Total production	Average annual production			Total production	Average annual production			Total production	Average annual production			Total production	Average annual production		Total production	Average annual production	
Alabama.....	709	679	136	57	443	2,036	407	342		149	30										814	163	186
Arizona.....	17,612	311	62	311	6,758																58	12	58
Arkansas.....	7,731	22,919	4,584	6,079	9,173	17,316	3,463	1,075	6,082														
California.....	24,067	158	32	158	68	87	17	87												6	1		
Colorado.....	4,821	224	45	224	112,354	33,619	6,724	3,303	11,714														
Georgia.....	6,679	13,786	2,757	3,572	9,510	26,813	5,363	10,088	1,266	6,124	1,225	205											
Idaho.....						476	95	313															
Massachusetts.....						2,549	510	1,900															
Michigan.....					22,673	9,627	1,925			44,413	8,883	18,617											
Minnesota.....					630,827	580,475	116,095	248,732	229,869	3,540,800	708,178	797,642											
Montana.....	199,932	37,781	7,556	8,230		46,157	9,231	3,617						36,191	7,238	9,271					11,646	2,329	1,842
Nevada.....	19,872	210	42	210	80,354	5,146	1,029	4,613													43	9	
New Jersey.....	64																146,796	563,058	112,614	154,355			
New Mexico.....	3,126	1,822	364	45	32,907	93,678	18,736	36,835	400														
North Carolina.....	315	43	9		39	241	48	190															
Oregon.....	198																						
South Carolina.....	100				850																		
South Dakota.....	31																						
Tennessee.....	4,162	21,785	4,357	6,983	2,307	4,083	817	2,327	51												4,712	942	435
Texas.....	380	38	8																				
Utah.....	5,100	1,744	349	27		8,774	1,755	2,102															
Virginia.....	10,928	3,980	796	1,043	7,859	12,780	2,556	4,482	4,917	77	15	77									5,565	1,153	1,173
Washington.....		10	2																				
West Virginia.....		2,213	443	219																	173	33	
Wisconsin.....									*215,839	405	81												
Wyoming.....	42																						
Totals.....	305,869	107,703	21,542	27,158	916,113	843,855	168,771	320,006	470,138	3,592,058	718,412	816,541		36,191	7,238	9,271	146,796	563,058	112,614	154,355	23,217	4,642	3,694
									*Approx. 5 $\%$ Mn				(Battery ores: High-grade manganese dioxide is required, low in iron, and free or very nearly free from electro-negative metals such as copper, nickel, and cobalt. Some concentrated domestic ores are being used, from Montana and California.)				(Manganiferous zinc residuum: A by-product resulting from the roasting of franklinite concentrates at Franklin Furnace, N. J. Contains 12 $\%$ -15 $\%$ manganese.)				(Miscellaneous ores: Ores shipped to brick and pottery manufacturers, glass makers and manufacturers of manganese chemicals; ores containing about 85 $\%$ MnO <sub>2</sub> and not more than 1 $\%$ iron.)		

\*\*Data from *Mineral Resources of the United States*.



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# UTILIZATION OF CALIFORNIA MANGANESE ORES

By O. CUTLER SHEPARD \*

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## INTRODUCTION

A successful mining operation can be carried out on a mineral deposit only when marketable products can be produced at a profit. The operation is simplest when the bulk of a large mineral deposit yields crude ore that satisfies the requirements of the consuming industries. Greater costs are involved in mining small and spotty deposits as well as in treating low-grade ores which require beneficiation.

In the past, the California manganese mining industry has been unable to compete with foreign ore from the comparatively large and rich manganese deposits of India, Russia, Africa, and Brazil. During the first World War the importation of foreign ore became difficult and, with expanding industry, the price of manganese ore in the United States more than doubled. During 1918 over \$60 per long ton was paid for manganese ore containing 50 percent manganese. Under these conditions a manganese mining industry developed in California and 24,000 tons of ore was produced in 1918. After the war foreign manganese ores again became available and the price rapidly declined to \$30 per long ton for 50 percent manganese ore. California manganese miners were unable to produce ore and ship it east to sell at this price, and manganese mining practically ceased in the State.

War conditions have again stimulated the development and operation of manganese mines in California. Whether or not this industry can profitably continue after the war depends on whether recent developments in the manganese-consuming industries and new developments in ore-treatment processes give California ores greater advantages than they had in 1919.

## MANGANESE-CONSUMING INDUSTRIES

The iron and steel industry consumes over 90 percent of all the manganese ore used in the United States. Nonferrous manganese alloys, dry-cell manufacture, the glass and ceramic industry, welding-rod coatings, and the production of various chemical compounds of manganese for use

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as paint and varnish driers and as germicides and deodorizers consume the balance of the ore.

#### The Iron and Steel Industry

Manganese is essential to the iron and steel industry. It is charged in the form of manganese ore to blast furnaces to produce pig iron containing manganese, and it is also added in the form of ferroalloys such as ferromanganese, spiegeleisen, or silicomanganese, during steel making.

Aside from war conditions, the situation with regard to the use of California manganese ores in eastern iron and steel plants remains unchanged. It seems likely that after this war, as in 1919, California ores will be unable to compete with foreign ores at eastern iron and steel plants. There is one favorable new development in the iron and steel industry, however, which may result in a continued use of California manganese ores. This is the new iron and steel plant of the Kaiser Company at Fontana, California. Steel-making furnaces have been in use in California for years but these do not locally consume manganese ore. Steel plants use manganese in the form of ferroalloys, and manganese ferroalloys are not at present produced in California. The Fontana plant differs from previously existing California plants in that it contains a blast furnace to produce its own pig iron and in this operation manganese ores are used. The Fontana blast furnace is said to have a capacity of 1200 tons of pig iron per day. Basic pig iron should contain at least 1 percent of manganese, and since only about 70 percent of the manganese charged enters the pig, roughly 34 tons per day are required if a 50 percent manganese ore is used. For the Fontana blast furnace, manganese ores in southern California should have the advantage of low transportation costs to the consuming plant. At the present time, however, at least a part of the manganese ore used at Fontana comes from Lower California.

In a letter\* to the State Mineralogist, Ramsay has described the use of California manganese ore at Fontana and has supplied a list of shippers.

Manganese ore need not be high-grade for use in the iron blast furnace. A large silica content is objectionable but the ratio of manganese to iron is not important. It is desirable that the ore be in lump form so that it will not impede the blast or blow out of the furnace. Fine ore could be sinter-roasted but this involves extra expense.

Although ferromanganese spiegeleisen and silicomanganese are not at present produced in California, the possibility of future production should not be overlooked. Conditions favoring such production are: (1) increased consumption of ferromanganese due to an increase in steel-producing capacity on the Pacific Coast; (2) an increase in the amount of low-cost hydroelectric power which is being made available in California; and (3) the possibility of electric furnaces, now used to produce ferro-silicon for the Pidgeon process of producing magnesium, becoming available after the war for the production of the ferroalloys.

\* Personal communication by George D. Ramsay, Director of Laboratories and Materials Development, Iron and Steel Division, Kaiser Company, Inc., Fontana, California.

"Manganese ore is charged into the blast furnace at the Kaiser Company, Iron and Steel Plant, at Fontana, California. Its purpose is to give the pig iron the manganese content desired by either the open hearth or the customer. Approximately 75% of the manganese charged into the blast furnace enters the iron. About 30,000 tons, on the basis of 30%, of manganese ore is used per year, under present practice."

Ferromanganese and spiegeleisen are commonly produced in blast furnaces but electric furnaces are also used. Blast-furnace production of ferromanganese in California does not appear economical because the coke consumption is high and coke is relatively expensive in California. Electric-furnace smelting of manganese ores in California to produce ferromanganese and silicomanganese appears feasible. Compared with blast-furnace smelting the electric-furnace operation is easier to control, gives a greater recovery of manganese, requires less flux, and can produce ferroalloys of lower carbon content.

If the production of ferromanganese should develop in California, a considerable demand should appear for local ores which would have the

*List of shippers  
California manganese*

<i>Shipper</i>	<i>Shipping point</i>	<i>Long dry tons shipped</i>	<i>Average percent manganese (dry basis)</i>
Halifax-Tonopah Mining Company Attn. Frank W. Cole 123 East Lime Street Monrovia, California	Fields Siding San Bernardino County California	36	39.17
K & S Mining Company c/o 1st National Bank Building Bellflower, California	Manix San Bernardino County California	107	31.00
A. B. Miner Arlington Manganese Company Box 558 Blythe, California	Inca Station Riverside County California	5899	23.44
Frank W. Orr 339 S. Figueroa Street Los Angeles, California	Rand Siding Kern County California	21	16.90
W. E. Otto 255 California Street San Francisco, California	Manix San Bernardino County California	581	29.86
Pacific Coast Manganese Company San Miguel California	Ascension Siding San Luis Obispo County California	197	14.34
Z. E. Page 221 North Main Street Porterville, California	Lindsay Tulare County California	128	14.82
Suckow-Borax Mines Consolidated, Inc. 2466 East 56th Street Los Angeles, California	Newberry San Bernardino County California	47	19.36
W. E. Thurber 116 North Madison Avenue Monrovia, California	Pisgah San Bernardino County California	180	19.78
War Manganese Company 720 Subway Terminal Building Los Angeles, California	Ruthven Imperial County California	50	31.98
V. B. Whedon 9470 Santa Monica Boulevard Beverly Hills, California	Glamis Imperial County California	653	24.42

advantage of lower transportation costs. The amount of ferromanganese which might be used on the Pacific Coast depends on the amount of steel produced, at least 13 pounds of manganese being required for each ton of steel.

The suitability of a manganese ore for the production of ferromanganese depends on the ratio of manganese to iron, on the phosphorous content, and on the silica content. A 10 to 1 ratio of manganese to iron is desired. The phosphorous content should be low (foreign ores average about 0.1 percent phosphorous). The silica content should be below 8 percent. For blast-furnace production of ferromanganese the ore should be in hard lumps, as fine and soft ores obstruct the blast and cause loss in the flue dust. The size and physical condition of the ore are not so important in electric smelting.

Manganese ores which contain more silica than that allowed for the production of ferromanganese, and which are low in iron, could be used for the production of silicomanganese; but the demand for this product is small in comparison with that for ferromanganese.

#### Nonferrous Manganese Alloys

Manganese is an important alloying element in the formation of alloys of copper, zinc, aluminum, and magnesium. The percentage used in any one alloy is small, however, and the total consumption of manganese for these alloys is almost insignificant in comparison with the amount used in the iron and steel industry.

Manganese metal, for forming nonferrous alloys, has been produced in the east mainly by silicon reduction of high-grade manganese ore in an electric furnace. A product containing from 95 to 98 percent of manganese, a maximum of from 2 to 3 percent of iron, a maximum of 1 percent silicon, and a maximum of 0.25 percent of carbon was produced in this way.

Development of uses for manganese metal and uses for alloys having a high manganese content have undoubtedly been retarded by the high cost and relatively poor quality of the available manganese metal. Within the last few years, however, an electrolytic process for the production of manganese metal has developed into a commercial process. Electrolytic manganese containing 99.9 percent manganese is now on the market at a price of about 38 cents per pound. Early in 1942 the production of electrolytic manganese by the Electro Manganese Corporation of Knoxville, Tennessee, amounted to 2 tons of metal per day. Since that time the capacity is said to have doubled.

New uses for high-purity manganese have not developed as rapidly as expected. The wartime 5-cent piece now contains 35 percent silver, 56 percent copper, and 9 percent manganese. An alloy containing 50 percent manganese with nickel and copper has proved satisfactory for electrical resistors, other than heating elements. Various high-manganese alloys with copper, nickel, and zinc, that have interesting properties, have been reported by Anderson.<sup>1</sup>

The electrolytic process of producing manganese metal can make use of low-grade manganese ores. According to Counselman<sup>2</sup> the Electro

<sup>1</sup> Anderson, C. Travis, Properties of some new manganese alloys of probable commercial significance. Paper presented at dedication of Bureau of Mines Experimental Station, Salt Lake City, Utah, May 21, 1940.

<sup>2</sup> Counselman, T. B., Ore concentrating and milling: Mining and Metallurgy, February 1943, p. 59.

Manganese Corporation uses ore from Batesville, Arkansas and also uses some of the Chamberlain nodules from South Dakota. The Chamberlain nodules occur in shale and consist of mixed carbonates of manganese, iron, and calcium. The U. S. Bureau of Mines<sup>3</sup> reports that the nodules comprise from 5 to 16 percent of the shale and have the following analysis:

Mn	-----	15.71%
Fe	-----	11.14
P	-----	0.43
SiO <sub>2</sub>	-----	13.30
Al <sub>2</sub> O <sub>3</sub>	-----	2.69
CaO	-----	15.00
MgO	-----	1.80
CO <sub>2</sub> ignition loss	-----	26.00

Manganese metal is used in California for alloying with aluminum and magnesium. California has manganese ore, low-cost power, and the chemicals used in the electrolytic process are produced here. These factors favor the operation of an electrolytic manganese plant in the State which may eventually furnish a local market for low-grade ore.

#### Dry-Cell Manufacture

Manganese ore, containing manganese in the form of MnO<sub>2</sub>, is one of the major constituents of the ordinary dry cell. A high-quality ore is required for battery use and only certain ores are suitable. For this reason the price of chemical (battery-grade) manganese ore is greater than that of metallurgical ore. For example, in 1940 when metallurgical ore sold for 50 cents per long-ton unit of contained manganese, battery-grade ore containing 70 percent MnO<sub>2</sub> sold for \$45 per long ton, f.o.b. mines. The 70 percent MnO<sub>2</sub> ore contains 43 units of manganese and hence would have sold for only \$21.50 at iron and steel plants.

The price of battery ore has been sufficiently high to make mining of this kind of manganese ore profitable in the United States during normal times. For years a considerable production has been made in the Philipsburg district of Montana, much of it coming from ores which require beneficiation by magnetic and gravity methods in order to produce a concentrate suitable for battery use. In 1940 the only domestic production of battery ore came from Montana, which shipped 9,271 long tons, while in the same year 27,405 long tons of battery-grade ore was imported.<sup>4</sup>

#### General Dry Batteries, Inc.

Recently General Dry Batteries, Inc. have discovered that oxidized manganese ores near Patterson, California, are particularly well suited for battery use. Under the direction of Mr. Edwin Lavergne, a mill has been built near Patterson to beneficiate these ores for battery use. A photograph of the mill, which has been in operation since February 1943, is shown in figure 1, and a diagram of the mill flow sheet is given in figure 2. At the Patterson mill, manganese ores are put through a jaw crusher set at  $\frac{3}{4}$ -inch, then dried in a closely controlled gas-fired kiln at not over 125° C. to 0.2 percent moisture. The dry ore is further crushed in rolls, one of which is in closed circuit with a 12-mesh Hummer screen. Minus 12-mesh ore is screened on 30- and 60-mesh Hummer screens to produce a 12/30-mesh product, a 30/60-mesh product, and a minus

<sup>3</sup> DeVaney, F. D., Shelton, S. M., and Lamb, F. D., Concentration of manganese nodules from Chamberlain, South Dakota: U. S. Bur. Mines Rept. Inv. 3613, p. 4, 1942.

<sup>4</sup> Ridgway, Robert H., Davis, H. W., and Matthews, Allan F., Manganese and manganiferous ore: Minerals Yearbook 1940, p. 583, 1941.



Fig. 1. Plant of General Dry Batteries, Inc., near Patterson.  
*Photo by Olaf P. Jenkins.*

60-mesh product. The 12/30-mesh and 30/60-mesh products are run through magnetic separators which produce a magnetic concentrate and tailings. The grade of the minus 60-mesh product varies with the grade of the original ore. Usually it is rich enough to add to the concentrate and then a manganese recovery of over 95 percent is said to be obtained. With low-grade ores the minus 60-mesh product is discarded and the recovery drops accordingly. Concentrates are ground at the mill to about 90 percent through 325-mesh in a ball mill which is in closed circuit with an air classifier. The finished product is collected in a cyclone dust collector and bagged for shipment to the battery plant in Cleveland, Ohio.

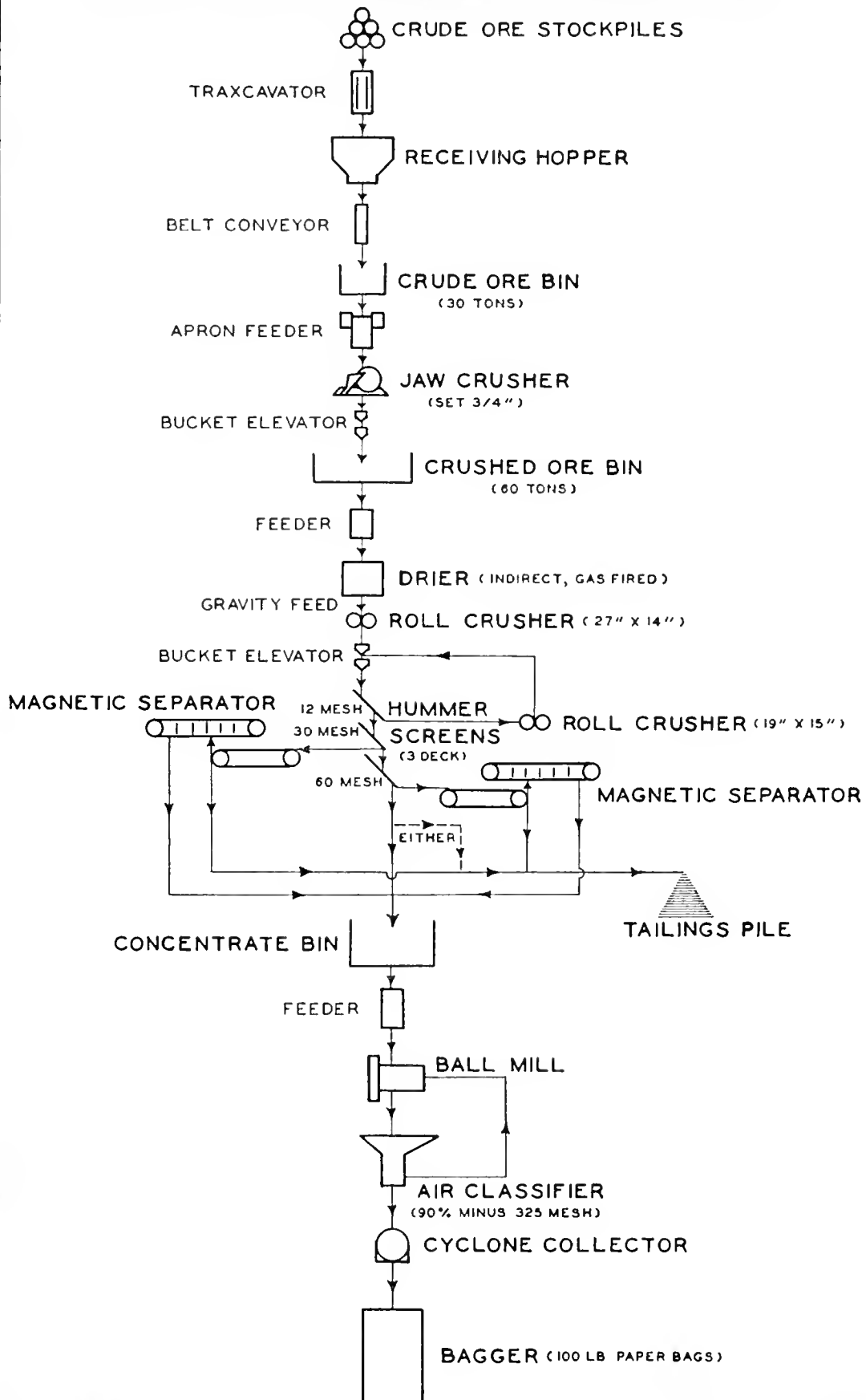
According to Lavergne, the Patterson mill will be able to use sufficient ore to produce 1000 tons of concentrates per month. The termination of the war will not affect the demand for Patterson battery ore because of its superior quality. Patterson ore, with a 70 percent  $\text{MnO}_2$  content, is said to be the equal of African ore containing 85 percent  $\text{MnO}_2$ .

This assured demand for battery ore in California should stimulate the search for greater quantities of suitable ore. The amount of known ore in the mines near Patterson is limited because, in depth, primary ore containing rhodochrosite is encountered. Rhodochrosite, without expensive chemical treatment, is not suitable for dry-cell manufacture.

Battery ore must contain manganese in the oxidized condition, but neither the  $\text{MnO}_2$  content of an ore nor its available oxygen determine for certain the quality of an ore for battery use. According to Birdsall<sup>5</sup> the only sure method of testing is to make sample dry cell batteries and subject them to standard discharge tests. Zinc corrosion tests must also be made and several months are required to complete these tests. Prospectors may obtain an opinion as to the suitability of their ore for battery use by submitting a 25-pound sample to the Patterson Unit of General Dry Batteries, Inc.

<sup>5</sup> Private communication from Charles G. Birdsall, Director of Laboratories, General Dry Batteries, Inc.

# PATTERSON MILL FLOWSHEET



C.S.O.M.

Fig. 2. Patterson Mill flowsheet

### The Glass and Ceramic Industry

Manganese dioxide has been used to prevent the formation of a yellowish-green color in glass by the small amount of iron usually present in glass sands. Selenium has largely replaced manganese for this use because glass decolorized with manganese tends to assume a pink color on long exposure to sunlight. A small amount of manganese ore is still used for decolorizing optical glass and as a coloring agent in black glass. Ores containing about 85 per cent  $\text{MnO}_2$  and not more than 1 percent iron are used for the glass and ceramic industry.

Manganese compounds produce a rich brown color in ceramic glazes, and manganese ore is also used as a coloring agent for bricks and pottery. The tonnage of manganese ore used in the ceramic industry is relatively small.

### Welding-Rod Coatings

Modern arc welding is usually carried out with coated electrodes. Ferromanganese is commonly used in the coatings, for deoxidation, and the coatings on some rods contain manganese dioxide from high-grade manganese ore.

The wartime construction of ships by arc welding has resulted in a great expansion in the production of welding rods and some California manganese ores are used in the local production of welding-rod coatings.

Undoubtedly this industry will continue after the war, but it is likely to be greatly curtailed.

### Driers and Other Chemical Uses

A relatively small amount of manganese ore is regularly used for the production of manganese sulphate. This salt is manufactured by various processes for the production of many different chemical compounds of manganese.

For use as driers in paint, varnish, and printing ink, compounds such as natural or artificial manganese dioxide, manganese hydrate, borate, chloride, sulphate, resinate, linoleate, or oxalate are used.

Other chemical uses of manganese compounds include manganese dioxide in the manufacture of hydroquinone and potassium permanganate, as an oxidizing agent having a wide variety of uses.

## MANGANESE ORE-TREATMENT PROCESSES

There has been much recent activity directed toward the production of ferro-grade material from low-grade manganese ores. Plants using various kinds of concentration, leaching, and pyrometallurgical processes are in commercial or experimental use.

Most of this activity has been in an effort to develop domestic supplies of manganese for steel making during war. The economics of post-war treatment of low-grade California manganese ores to produce material for use in eastern ferroalloy plants does not look encouraging.

### Concentration of Manganese Ores

Manganese ores vary widely in chemical and physical properties and consequently different types of concentration processes are suitable for different ores. Hand sorting, jigging, tabling, flotation, magnetic separation, and log washing have all been used.



Washing, hand sorting, and jigging are being used at several plants treating Appalachian manganese ores. Descriptions of plants and operating results are given by Newton.<sup>6</sup> The future of these concentration plants does not look bright. In 1930 a 30,000-ton per year manganese concentration mill with jigging and tabling was constructed in the Woodstock district of Virginia. Metallurgical results were said to be satisfactory but due to unfavorable economic conditions the mill closed down after a short period of operation.

Flotation concentration followed by nodulizing produces concentrates meeting ferromanganese ore specifications from low-grade oxide ore in Cuba<sup>7</sup> and carbonate ore in Montana.<sup>8</sup> A flotation concentration mill is more expensive to build and to operate than a mill using jigs and tables, consequently flotation is used for manganese ores only when fine grinding is required to liberate the minerals.

Magnetic concentration is used to concentrate battery ore at mills in Montana and in California. Magnetic separators give good results on crushed ore which has been dried and closely sized. Fine ore particles (minus 100-mesh) do not separate as completely as do the coarser particles. There is always a considerable amount of fine material unavoidably produced and the disposal of the material which is too fine to be readily separated has always been a problem at mills using magnetic concentration.

Sink-and-float concentration, using a fluid suspension of ferrosilicon has proved successful in the concentration of iron ores.<sup>9</sup> Since the concentration requirements of some manganese ores are similar to those of iron ores, this new process should be kept in mind for low-grade manganese ore.

#### Leaching of Manganese Ores

Hydrometallurgical processes of various kinds are being tried for the leaching of manganese from low-grade ores. The leach solutions are either treated by electrolysis to produce electrolytic manganese metal or treated to precipitate a high-grade manganese product suitable for making ferromanganese. The new Three Kids plant of the Manganese Ore Company, located near Las Vegas, Nevada, is of the latter type. Mention has already been made of the electrolytic process of the Electro Manganese Corporation.

#### Pyrometallurgical Treatment of Manganese Ores

The Bureau of Mines<sup>10</sup> is experimenting with a matte smelting process for low-grade manganese ores. In this process the manganese from low-grade ores is obtained in a high-grade manganese matte which is then roasted and sintered to obtain a material suitable for the production of ferromanganese. So far only experimental plants have used this process.

<sup>6</sup> Newton, Edmund, Mining and beneficiation of Appalachian manganese ores: U. S. Bur. Mines Inf. Circ. 7145, 46 pp., 1941.

<sup>7</sup> Norcross, F. S. Jr., Development of low-grade manganese ores of Cuba: Am. Inst. Min. Met. Eng. Tech. Pub. 1188, 13 pp., 1940.

<sup>8</sup> Hutt, John B., Domestic manganese from Butte helps in emergency: Eng. and Min. Jour., January 1942, p. 56.

<sup>9</sup> Holt, Grover J., Development of sink-and-float concentration on the Iron Ranges of Minnesota: Am. Inst. Min. Met. Eng. Tech. Pub. 1621, 6 pp., 1943.

<sup>10</sup> Wood, C. E., Barrett, E. P., and Porath, P. R., Matte smelting of manganese: U. S. Bur. Mines Rept. Inv. 3545, 15 pp., 1940.

Knickerbocker, R. G., and Miller, Virgil, Smelting of manganese oxide, carbonate, or silicate ores with copper and iron sulfide: U. S. Bur. Mines Rept. Inv. 3659, 23pp., 1942.



# MANGANESE DEPOSITS OF CALIFORNIA

## A SUMMARY REPORT

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United States Department of the Interior, Geological Survey  
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### INTRODUCTION

During the field seasons of 1940, 1941, and 1942 the Geological Survey, United States Department of the Interior, investigated the manganese resources of California. This investigation was part of a comprehensive study of strategic minerals which is being carried on by the Survey and the Bureau of Mines, also of the Interior Department. The work on California manganese consisted, in its early stages, mainly of mapping a few selected areas in detail, with a view to learning, first, how the deposits were formed and, second, how deposits of various kinds can be recognized from their outcrops. Later, especially after the United States entered the war, the Survey directed its efforts mainly toward appraising the possibilities of each individual deposit in the State. Manganese deposits are widely distributed through California, having been found in 44 of its 58 counties. Some 350 deposits have been examined by members of the Survey, and information has been compiled regarding 300 additional deposits that have been examined by other persons. The material thus gathered, by direct observation and at second hand, is summarized in the present report.

Readers who seek local information will find it stated most fully in the part of the report headed *Distribution of Manganese Deposits in California*, which contains for each county in which manganese deposits occur a general account of its manganese resources. Under the heading *Tabulated Data on Manganese Properties of California* are listed, by counties, the name, ownership, location, production, and character of each individual deposit.

The members of the Geological Survey who participated in the field work are Edgar Bowles, D. C. Cox, S. C. Creasey, M. D. Crittenden, Jr., Fred Gros, J. B. Hadley, C. B. Hunt, S. G. Lasky, John Livermore, John Nelson, W. G. Pierce, R. J. Roberts, A. F. Shride, F. S. Simons, P. D. Trask, F. D. Trauger, C. R. Warren, J. H. Wiese, and I. F. Wilson. The work was supervised by S. G. Lasky until May, 1941, and by P. D. Trask for the remainder of the time.

Most of the records used herein that describe investigations of manganese deposits not recently visited by members of the Geological Survey come from the unpublished reports prepared, in 1917 and 1918, by the California State Council for Defense, in cooperation with the

Geological Survey and the Bureau of Mines. That work was done, under the direction of George D. Louderback, by T. H. Crook, E. F. Davis, F. S. Hudson, R. R. Morse, N. L. Taliaferro, A. O. Woodford, and other geologists. Other data came from the report on manganese published in 1918 by the California State Division of Mines (Bradley, W. W., et al. 18). Some came from an unpublished report on manganese in California prepared for the California State Division of Mines in 1941 by Robert S. Kroger (41) and the remainder came from miscellaneous sources, which are indicated in the explanation to the tabulated list of deposits.

## GENERAL ASPECTS OF THE MANGANESE INDUSTRY

### Production

The annual world production of manganese during the ten years prior to 1940 ranged from a minimum of 1,300,000 tons in 1932 to a maximum of 6,000,000 tons in 1937. During this period the United States production ranged from 18,000 tons in 1932 to 67,000 tons in 1930, and the average annual production from California was 100 tons (Groves, W. A. 38, p. 27). The largest production from California in any one year was 24,000 tons, in 1918, and, although the first ore was produced in 1867, the total production has been less than 100,000 tons. Prospecting and development of manganese in California have been stimulated by the advent of the present war, but recent production figures are not available.

### Uses<sup>1</sup>

Manganese is used principally in steel manufacture, some 13 pounds being required for the production of each ton of steel. The manganese removes oxygen and sulphur from the steel and aids in controlling the carbon content, and a small part passes into the steel itself, imparting to it certain desirable properties. The manganese is mostly added in the form of ferro-manganese, which is an alloy of manganese and iron containing about 80 percent of manganese. For the preparation of ferro-manganese, an oxide ore is desired that contains at least 48 percent of manganese and not more than 7 percent of iron, 6 percent of alumina, 10 percent of silica, 1 percent of zinc, or 0.18 percent phosphorus. An alloy of manganese and silicon, called silico-manganese, is sometimes used in the manufacture of steel, but as the slag from this alloy is more viscous than that from ferro-manganese not much silico-manganese has been used in this country. Spiegeleisen, which is about 80 percent iron and about 20 percent manganese, is also used to some extent in the production of steel.

Manganese is also employed in making permanent alloys. Steel containing about 12 percent manganese has high tensile strength and is much used for frogs at railroad crossings. When alloyed with chrome and nickel steels, with aluminum, with copper, and with various bronzes, manganese increases resistance to corrosion.

Manganese ore is used, without being reduced to metal, in making dry-cell batteries. Ore that is to be employed for this purpose must be high in available oxygen and low in metals that react electrically with zinc, such as iron, copper, nickel, cobalt, and arsenic. The manganese

<sup>1</sup> Compiled from Groves, W. A. 38, pp. 14-23.

oxide ore found in the eastern part of the central Coast Ranges of California, in Santa Clara and Stanislaus Counties, is very suitable for use in batteries, and the General Dry Battery Company has recently erected a concentrating plant near Patterson, in Stanislaus County.

Small quantities of manganese are used in the glass industry for removing iron from glass; in ceramic industries as a pigment for purple, brown, and black glazes; in paint manufacture for facilitating the absorption of oxygen by linseed oil during the drying of the paint, and for making white, green, brown, and black pigments; in chemistry for manufacturing chlorine and for purifying the zinc solutions used in making lithophone; and in agriculture as a fertilizer.

#### Types of Ore

The principal commercial ores of manganese are of six types, characterized respectively by: (1) black oxides, (2) hausmannite, (3) braunite, (4) rhodochrosite, (5) wad, and (6) manganiferous iron. Ores of all these types are found in California. The most abundant ore that is mined is of the black oxide type. Such ore may contain several different minerals that consist essentially of manganese oxide, but these minerals cannot be distinguished with certainty except by X-ray methods (Fleischer and Richmond 43). When pure they contain from 63 to 68 percent of manganese and consist mainly of  $\text{MnO}_2$  or  $\text{Mn}_2\text{O}_3$ , but they commonly contain subordinate quantities of aluminum, barium, calcium, cobalt, potassium, lead, lithium, iron, and other elements. Soft black oxides have often been referred to in the past as pyrolusite, and hard black oxides with a bumpy or botryoidal external form have been called psilomelane; but recent work by Fleischer and Richmond indicates that hardness is not a certain means of determination, and no attempt, therefore, has been made in this paper to distinguish the black oxides from one another.

Hausmannite ( $\text{Mn}_3\text{O}_4$ ) is a dark reddish-brown mineral having a brownish streak. It contains, when pure, 72 percent manganese, but the best found in California contains only about 56 percent. Braunite ( $3\text{Mn}_2\text{O}_3 \cdot \text{MnSiO}_3$ ) is a hard, dense, steel-gray mineral, which is soluble in hydrochloric acid and leaves a jelly when the acid is dried off. Pure braunite contains 60 percent manganese, but as ordinarily found, the mineral contains only about 50 percent. Rhodochrosite ( $\text{MnCO}_3$ ) occurring in veins is commonly light pink, but where it occurs in beds it may be pink, white, or gray. It can be scratched, though not easily, with a knife, and it effervesces slightly with acid. It forms both fairly large crystals and fine-grained aggregates. The fine-grained variety has a peculiar greasy luster which helps to identify it. Pure rhodochrosite contains 48 percent manganese, but that found in nature ordinarily contains less than 44 percent. It is used as a source of manganese for chemicals and fertilizer, and, after being calcined, for making ferro-manganese. Wad contains oxides of manganese, iron, and other metals, mixed with clay or other impurities. It generally contains much water, and its manganese content seldom exceeds 20 percent. Some iron ore that contains considerable manganese is mined for use in making spiegeleisen.

The manganese minerals named above are the ones most commonly mined, but manganese is a constituent of many other minerals, a few

of which may constitute ores. Two manganese silicates, bementite (a hydrous manganese silicate) and rhodonite ( $\text{MnSiO}_3$ ) are found at many places in California, but, although rhodonite ordinarily contains about 38 percent manganese and bementite 15 to 40 percent, their high silica content and refractory nature detract from the possibility of their utilization as ores.

Further details on manganese minerals are given below in the section on aids to prospecting.

#### Treatment of Ores

Most manganese ore is shipped crude; though in places, notably in the Appalachian states, the ore is concentrated by mechanical methods. The oxide ores of California are not very amenable to mechanical concentration, and, although electromagnetic and electrostatic methods are said to have been applied to them with some success, they must in general be hand picked. Some rhodochrosite ores are concentrated by flotation, but much of the rhodochrosite in California is so pure that it probably could be shipped without concentration. The manganese in low-grade oxide ores, and also that in rhodochrosite, braunite, and bementite, is soluble in  $\text{SO}_2$  or  $\text{SO}_3$ , and leaching with these substances may prove feasible in case enough ore can be found to warrant the construction of a leaching plant.

#### Schedule of Metals Reserve Company Prices

The Metals Reserve Company, a subsidiary of the Reconstruction Finance Corporation, purchases carload lots of manganese ores in California, under contract, for delivery to the stockpile at Sacramento. The current specifications for manganese ore are as follows:

The terms under which Metals Reserve Company will purchase domestic manganese ores are subject to change without notice, and the terms and provisions of each contract will be based on conditions and circumstances existing at the time of acceptance. The policies herein outlined do not apply to ores originating outside the limits of continental United States.

1. *Quantity*: One thousand (1,000) to ten thousand (10,000) long tons per contract. Contracts in excess of ten thousand tons may be obtained as a result of individual negotiations, provided reliable and complete engineering data submitted by the applicant warrant a contract for a larger quantity.

2. *Term of contract*: Deliveries must be completed within eighteen (18) months of date of contract. If delivery of twenty per cent (20%) of the tonnage contracted for has not been made within six months of date of contract, Buyer may cancel contract forthwith.

3. *Quality*: Ores and concentrates will not be accepted under this schedule which contain less than 35% manganese, more than 3% zinc, or more than 1% phosphorus.

*Size*: None in excess of 12 inches and not more than 25% to pass a 20-mesh screen. Material not meeting size specifications will be accepted only on a negotiated basis.

4. *Price*: Contracts will be considered on the following schedule for domestic ores and concentrates within continental United States (excluding Alaska); all prices per long ton unit (2,240 pounds), dry weight, f.o.b. cars at stockpile designated by Buyer.

#### BASE PRICE

\$1.00 per unit of contained manganese (\$48.00 per long dry ton of 2,240 pounds) for ores and concentrates analyzing as follows:

Manganese -----	48.00%
Iron -----	6.00%
Silica plus alumina-----	11.00%

#### PREMIUMS

Manganese content—*Above 48%*:  $\frac{1}{2}\text{¢}$  per unit of contained manganese for each 1% of manganese content.

Iron content—*Below 6%*:  $\frac{1}{2}\text{¢}$  per unit of contained manganese for each 1% of iron content.

Silica plus alumina content—*Below 11%*: None.

## PENALTIES

- Manganese content—*Below 48%: 1¢ per unit of contained manganese for each 1% of manganese content down to and including 44%.*  
*Below 44%: 4¢, plus 1½¢ per unit of contained manganese for each 1% of manganese content down to and including 40%.*  
*Below 40%: 10¢, plus 2¢ per unit of contained manganese for each 1% of manganese content down to and including 35%.*
- Iron content—*Above 6%: 1¢ per unit of contained manganese for each 1% of iron content up to and including 8%.*  
*Above 8%: 2¢, plus ¾¢ per unit of contained manganese for each 1% of iron content.*
- Silica plus alumina content—*Above 11%: 1¢ per unit of contained manganese for each 1% of silica plus alumina content up to and including 15%.*  
*Above 15%: 4¢ plus ¾¢ per unit of contained manganese for each 1% of silica plus alumina content.*

Fractions prorated in all cases.

In addition to the above prices, an allowance will be made for each long ton accepted equal to the railroad freight tariff per long ton from Seller's nearest convenient rail station to Buyer's stockpile.

The cost of sampling and analysis by the Buyer, weighing, and unloading onto stockpile will be for the account of Buyer.

5. *Shipment and Delivery:* Seller will give such advice regarding shipment and arrival as Buyer may require at least ten days prior to shipment of the ore from point of loading onto railroad cars; otherwise, any demurrage at the stockpile will be for Seller's account.

Shipment will be made in flat bottom gondolas, if available, in lots of not less than one carload, to the stockpile designated by Buyer. Seller will prepay the freight to such stockpile, where the ore will be weighed in cars, light and loaded, on track scales, and sampled for moisture. The lot will be sampled as unloaded and upon receipt of analysis, Buyer will advise Seller as to whether the ore is acceptable and under what classification.

If the lot is ascertained to be unacceptable under the above specifications, Seller will not be entitled to any allowance for prepaid freight and will be held responsible for the removal of this shipment of ore from the stockpile location. Upon failure so to remove the ore within fifteen days of due notice, Buyer may, at its absolute discretion, remove such ore and the cost of such removal shall be for Seller's account; or Buyer may, at its option, otherwise dispose of such ore without any liability therefor. In the event that Seller fails to repay Buyer for the cost of removal within fifteen days after notice, Buyer may cancel the contract forthwith.

6. *Payment:* As soon as moisture and analysis determinations are received, Buyer will promptly pay Seller in accordance with the weight certificate and the above schedule.

7. *Weights:* The weight paid for will be net railroad track scale weights (weight of loaded car less weight of empty car), less moisture as determined by standard practice.

8. *Sampling and Analysis:* Each lot will be sampled at the time of unloading onto stockpile by a sampler designated by Buyer, three samples being taken, one each for Seller, Buyer and Umpire, and analysis made for manganese and other guaranteed elements. Usual provisions will be made for splitting limits and settlement by average of Seller's and Buyer's analyses, or by trade practice if samples are sent to Umpire. Moisture samples will be taken in accordance with standard practice. Seller may have representative at sampling at his own expense.

Metals Reserve Company,  
 Washington, D. C.,  
 May 15, 1943

## GEOLOGY OF CALIFORNIA MANGANESE DEPOSITS

The manganese of California occurs in many different ways. An outline summary of its various modes of occurrence is given in Table 1, *Classification of California Manganese Deposits*.

## Deposits of the Franciscan Type

## Typical Features

Most of the California manganese ore is found in chert of the Franciscan formation, which is extensively exposed in the Coast Ranges. The ore in the Franciscan formation follows the bedding, and, though it has been hydrothermally altered in places, it is of sedimentary origin. Deposits of the same type are found in older cherts in the Sierra Nevada.



The country rock of the Franciscan manganese deposits is mainly white or green chert, though a few deposits are found in red chert. Massive white chert seems to be especially favorable. The deposits in Santa Clara and Stanislaus Counties, in the central part of the State, are mostly in massive beds of white chert, which are as much as 40 feet thick in places, though generally less than 10 feet thick. In this region the orebodies tend to line up in certain stratigraphic zones, as if many had been formed at certain periods during which conditions were especially favorable.

The orebodies are generally flat and lie parallel to the bedding. The smallest are mere pods or lenses a few inches long; the largest have lengths of several hundred feet. The orebody at the Ladd mine (San Joaquin County) is 800 feet long, and those at the Thomas and Blue Jay mines (Mendocino and Trinity Counties, respectively), about 600 feet, but almost all the others are less than 200 feet in length. The most characteristic form of all except the very small orebodies may roughly be likened to huge, not always well-poured pancakes. The outline of the body may be almost circular, but in general it is elliptical, though the longer diameter is rarely if ever more than twice the shorter. The maximum thickness commonly ranges from about 5 to 10 percent of the greatest diameter, though in extreme cases it may be as little as 1 percent or, for small bodies, as much as 50 percent. Apart from minor fluctuations, an orebody tends to maintain its thickness within a few yards of the edge, and then to taper somewhat abruptly. The edge is likely to be rounded like the side of a man's tongue. The orebodies have commonly been tilted, together with the enclosing beds, at high angles, and their outcrops have the outlines of long, narrow ellipses or loops.

The most abundant primary ore mineral in the Franciscan deposits is a gray, fine-grained, nearly pure rhodochrosite, cut by widely spaced veinlets of quartz from a sixteenth to a quarter of an inch wide. The better, more massive ore is the most likely to be found in the thicker orebodies, though there are many exceptions to this rule. Massive ore tends to maintain its character to within a few feet of the edge of the orebody, where it grades into disseminated ore, which in its oxidized form is called stockwork ore. The primary manganese mineral in the disseminated ore is chiefly a silicate, presumably bementite, though rhombs and spherules of rhodochrosite up to an eighth of an inch in diameter are embedded in the chert at the margins of some orebodies. Bementite, however—or at least some hydrous silicate of manganese—is especially characteristic of low-grade ore.

Some of the orebodies contain no massive ore but consist entirely of disseminated (bementite?) ore. These low-grade bodies are ordinarily less than 3 feet thick. Their small size is a natural corollary of the fact that a large, rich orebody normally has a massive core surrounded by a rind in which the manganese minerals are disseminated. In the smaller bodies the rich core is lacking and only the lean rind is there.

Nearly all the orebodies are more or less oxidized at the outcrop, though primary ore is exposed at the surface in some places. The depth

of oxidation depends largely on rate of erosion. In the central Coast Ranges, oxidation extends to a depth of as much as 200 feet from the crests of some round-topped hills, but in the bottoms of nearby canyons primary ore may be found within 10 feet of the surface. In the more rugged mountains of northern California, the depth of oxidation is generally less than in the more subdued hills farther south.

The oxide ore derived from the rhodochrosite in the Franciscan deposits consists mainly of dark, sooty oxide, which may contain as much as 55 percent manganese. This material tends to silicify near the surface, where it may be dense, black, and of flinty hardness, but a few feet below the surface it is soft enough to be easily dug with a pick.

### Origin

Originally, it is believed, the Franciscan orebodies and the enclosing cherts were sedimentary deposits, accumulated in basins on the sea floor in regions where manganese carbonate and silica were being added to the sea water. It was presumably because of restricted circulation in such basins that these substances were kept from passing into the open ocean and becoming disseminated in the ocean water; thus confined, they could reach the saturation point and become precipitated. Conditions permitting deposition of silica evidently extended over wider areas than those permitting deposition of manganese carbonate. Lenses of chert in Stanislaus and San Joaquin Counties attain lengths of three or four miles, then taper out, only to reappear some miles away along the projection of the strike. In some places there is a gradation, along the regional strike, from shale or sandstone through thin-bedded red chert, thin-bedded white chert, and massive white chert to manganese ore; further along the strike, the same stages are passed through in reverse order. This distribution suggests that deposition of manganese carbonate was favored by reducing conditions; for the white, or more rarely green, chert that surrounds the manganese ore is obviously in a lower state of oxidation than the red chert by which the white or green rock is in turn surrounded. Rhodochrosite, moreover, contains manganese in its lowest state of oxidation, so that it would most probably be deposited in the inner parts of the basins, where reducing conditions prevailed in the highest degree.

### Varieties of the Franciscan Type

The best example of the Franciscan type of orebody that has been explored is in the Jones mine (Santa Clara County), but deposits from almost anywhere in the Franciscan formation illustrate its general habit. Most of the deposits, however, are complicated by modifications. The lower-grade deposits are relatively rich in bementite and poor in rhodochrosite; some deposits, indeed, of primary ore consist mainly of bementite or some similar hydrous manganese silicate; but it is uncertain whether or not the bementite is the original mineral. The ore on the winze level of the Ladd mine (San Joaquin County) is a good example of low-grade ore containing both carbonate and bementite.

The rhodochrosite in some deposits, notably that in the Charles Mountain mine (Humboldt County), is associated with shiny opaline neotocite (hydrous manganese silicate), which in part is later than the rhodochrosite. Other deposits, such as the Johe Ranch deposit (San Luis Obispo County), consist almost entirely of neotocite, but such deposits may have been altered thermally.

Hausmannite ( $Mn_3O_4$ ) seems at times to replace the primary rhodochrosite. In some places in the Blue Jay mine (Trinity County) hausmannite forms as much as 40 to 50 percent of the ore. The mineral is found in several other deposits in the Mad River Valley near the Blue Jay mine, and it is also present in the Buckeye mine (Stanislaus County). The hausmannite at these localities is dark purplish brown, though not so dark as most hausmannite, and has a dull luster. Operators in the upper Mad River country should be hesitant about throwing away any dark-brown ore, because it may contain hausmannite, which has a high manganese content. Hausmannite, however, may be confused with the much less valuable bementite, which is also dark brown; but bementite is waxy, whereas hausmannite is dull, and with practice the two minerals, at least the varieties found in the Mad River Valley, can be distinguished without serious difficulty.

An unusual variety of Franciscan ore is found in the Hale Creek mine (Trinity County) which is in the Mad River Valley, about 20 miles northwest of the Blue Jay mine. This consists of manganese carbonate mixed with a manganese silicate that is probably bementite. The ore contains about 38 percent manganese and 23 percent silica. In places it is cut by veins of silky radiating crystals of inesite (a complex manganese silicate) up to one-fourth inch in diameter. At the Fort Seward mine (Humboldt County), the primary mineral is braunite.

Masses of a chert-like rock, up to 100 feet in diameter, are found at some places near glaucophane schist or serpentine, where hydrothermal alteration has occurred (Cedar Tree deposit, Santa Clara County, and the White deposit, Trinity County). The rock is dense and looks much like massive chert, but in thin section it is seen to contain bementite, and it assays 15 to 20 percent manganese. On weathering, the mineral is altered to black oxide rich in silica. Deposits of this type do not yield much ore of shipping grade.

At many places in the drainage area of the South Fork of Trinity River, in Trinity County, large deposits of thin-bedded chert stained with manganese oxide are found in supposedly Paleozoic rocks. Such material contains only a small proportion of manganese, in most places less than 5 percent (Carr, Snowcamp, and Two Sugar Pines mines, Trinity County). One such deposit, on Elk Creek in Siskiyou County (Manganese 1, 2, 3, 4), contains a large quantity of this type of chert. Similar examples in the Franciscan formation are the Bear Ridge and Moody deposits (Trinity County). In Glenn County there are deposits of this type in sericite schist (B. S. No. 1 and Hummingbird).

#### Rhodonite Deposits

The principal primary mineral in most of the deposits on the west side of the Sierra Nevada is rhodonite. This mineral is found in beds of slightly recrystallized chert or fine-grained quartzite, forming part of

the Amador group,<sup>2</sup> occurring west of the Mother Lode (Custer, Du Frene, Amador County; Callahan, Daniels, Calaveras County; Hughes, Tuolumne County); and in highly recrystallized chert or quartzite interbedded with schist of the Calaveras series east of the Mother Lode (Gold Hill, Randel No. 1, Placer County; Pereni, Peyton, Amador County; Airola, Calaveras County). The deposits near Palmdale, in Los Angeles County, are also characterized by rhodonite occurring in the Pelona schist (Purple Sage and Red Feather deposits). The unoxidized rock in most deposits of this type contains less than 20 percent of manganese. The Sierra Nevada rhodonite orebodies are generally similar in form and size to the Franciscan deposits, and they are found in rocks that are known to be, or that could be, recrystallized chert. In some places the rhodonite forms massive bodies up to 3 or 4 feet in diameter; elsewhere it is disseminated in massive and thin-bedded quartzite, which alternates with slate, much as chert alternates with shale in the typical Franciscan chert. Most of the deposits are small and have produced little ore. They do not oxidize readily, and the primary minerals are found near the surface of the ground.

The manganese garnet spessartite occurs, usually with rhodonite, in schist of the Calaveras series from Calaveras County southward. In places it is the only primary manganese mineral. Rocks containing spessartite rarely contain over 15 percent of manganese. Some of the rhodonite deposits in the Sierra Nevada contain rhodochrosite. In these deposits the rhodonite seems to be later than the rhodochrosite and probably has replaced it as a result of metamorphism. There are other deposits in which rhodochrosite and bementite seem to be the primary minerals (Big Little Bear and Kellogg deposits, Calaveras County).

In Trinity County there are three fairly good-sized deposits containing rhodonite, bementite, and rhodochrosite—the Manganese Queen, Spider, and Lucky Bill. All three of the deposits are intimately associated with moderately basic plutonic intrusions. They are in chert, which apparently forms a roof pendant in the plutonic rock. In general the chief mineral of these deposits is rhodonite, but at some places either bementite or rhodochrosite predominates; the distribution of these three minerals is irregular. The deposits contain from 20 to 45 percent of manganese.

As all the rhodonite deposits are associated with rocks that seem to be recrystallized chert, the suggestion arises that they were formed by hydrothermal alteration of carbonate interbedded with chert.

Rhodochrosite is found in layers alternating with quartzite in one area near Oro Fino (Oro Fino No. 2, Siskiyou County). The deposits, which lie in a zone of recrystallized chert, are lenticular and are only

<sup>2</sup> The Amador group (Taliaferro 42, p. 89), originally named Tuolumne (Taliaferro 33, p. 149), is not distinguished on the Sierran folios, but it is a distinctive part of the bedrock complex which is especially significant in connection with the manganese deposits. It consists chiefly of dynamically metamorphosed clastic sediments and volcanics with frequent lenses of radiolarian cherts, in which the manganese deposits occur. The cherts usually are comparatively thin, discontinuous lenses, but, to the north and south of Merced River they attain a thickness of 1400 feet. The group occurs west of the Mother Lode, below the Mariposa group. The Amador group was mapped on the Sierran folios, according to Taliaferro, either as part of the Mariposa, as Calaveras, or as amphibolite, diabase, or porphyryite. Most of the manganese deposits west of the Mother Lode in Amador, Calaveras, Tuolumne, and Mariposa counties occur in the Amador group.

a few tens of feet in length. If they were larger they would make a promising source of manganese, for the rhodochrosite could be readily concentrated. They look much like metamorphosed Franciscan ore-bodies, but the rocks in which they lie are presumably older than the Franciscan.

#### Miscellaneous Bedded Deposits

In the Owls Head Mountains and Wingate Wash, south of Death Valley, deposits of low-grade wadlike manganese, similar to the Three Kids deposit near Las Vegas, Nevada, are found in Tertiary or later sediments (War Baby, Inyo County; Owls Spring, San Bernardino County). Some of these deposits are fairly large, but they contain only about 5 percent of manganese.

The Orchard deposits (San Bernardino County), near Lake Havasu, look much like sedimentary manganese, as they consist of massive beds of inclined fanglomerate in which manganese oxide forms the cement between the constituents. The strata are broken by fissures, however, and the mineralization on the two sides of some fissures is markedly different; the rock may indeed contain no manganese on one side of a fissure and 5 or 10 percent on the other. It therefore seems possible that these are fissure deposits, in which manganese solutions passing along the fissures have pervaded the sediments. The fanglomerate is exposed for a considerable distance, but the degree of mineralization varies along the strike. Though the tonnage of ore is relatively large, the grade is comparatively low. A smaller deposit of the same type is found north of the Chocolate Drop group in Imperial County.

#### Fissure Deposits

Throughout the desert, manganese oxides are found in brecciated rocks adjacent to fissures. Some of the fissures can be traced for a mile or more across country, but only in certain zones are the rocks along the fissures sufficiently mineralized to form ore shoots. These shoots range from a few feet to 500 feet in length, and from a few inches to 10 feet in width. The general depth of mineralization is unknown. In some places it goes as deep as 100 feet, in others less than 10 feet. The ore consists principally of hard manganese oxide, similar to psilomelane, but soft oxide and a radiating mineral reported to be manganite are present. Many of the deposits contain veins of white calcite which are clearly later than the manganese. The average manganese content of the deposits mined is from 15 to 30 percent. The hard oxide ore can be hand-sorted in some places to give a product containing 40 to 45 percent of manganese.

The best examples of these fissure deposits are in the Ironwood district (Arlington deposit, Riverside County), the Paymaster region in Imperial County (Whedon), and the Owls Hole district in San Bernardino County (New Deal and Emma deposits). These deposits produced several thousand tons of ore during World War I. Most of the other deposits of this type are either too small, too low in grade, or too remote from transportation to have been extensively developed.

The host rock for these deposits may be of almost any kind; it is volcanic rock in many deposits (Lugo, Imperial County; Taylor, Mono

County; Arlington, Riverside County; Black Raven, Northrup, Logan, Lee Yim, Big Reef, San Bernardino County); fanglomerate in the Chocolate Drop, Whedon, and War Manganese deposits of Imperial County, and the New Deal and Stewart deposits of San Bernardino County; granite in parts of Imperial County (Whedon deposit) and San Bernardino County (New Deal deposit); and limestone in the Langdon, Mountaineer, Paddy Faulkner, and Giant Chief deposits of Riverside County. At least one fissure deposit occurs along a contact between granite and limestone (Black Stone, San Bernardino County). In the Paymaster region in Imperial County, the extent of mineralization seems to decrease where the fissures pass from fanglomerate into granite, perhaps because the granite did not fracture as readily as the fanglomerate, and was less porous.

Many fissures in the more porous rocks, such as fanglomerate or brecciated volcanic rocks, contain a zone up to 10 feet wide of rock fragments surrounded by manganese oxide. These fissures commonly possess a smooth footwall and a gradational hanging wall (Lee Yim, Big Reef, and Stewart deposits, San Bernardino County). The more massive rocks, such as unbrecciated volcanic rocks and granite, more commonly contain definite veins of manganese oxide a few inches to one or two feet thick (Lugo deposit, Imperial County; Logan, Dawson deposits, San Bernardino County).

In some of these deposits of the so-called black calcite type, the oxide grades downward into calcite impregnated with oxide. Near the surface the calcite seems to have been leached away, causing the ore to be richer. Many small veins of manganese oxide also cut the rock and locally replace it. The origin of these deposits is not clear.

In a peculiar fissure deposit found at the Braitto or Iron Dyke mine in Plumas County, the ore is found along a strike fissure zone in a series of slightly metamorphosed sediments and volcanic fragmental rocks. The rocks adjacent to the fissure have been silicified in places to form lenticular masses of bright red and yellow jasper. The silicified masses are irregular in width, but in places they are more than 10 feet wide. At the Braitto mine the primary mineral is braunite, which forms a vein up to 5 feet in width. Associated with the braunite are quartz veins, which in places are studded with the manganese epidote piedmontite, and near the surface the piedmontite has oxidized, forming low-grade ore. The fissure zone extends across country for 5 or 10 miles, and in places it is associated with concentrations of manganese, most of which are of low grade, containing 10 to 20 percent of manganese.

The best example of a fissure deposit in limestone is the Langdon deposit in Riverside County, about 10 miles east of the Ironwood district, in which there are segregations and veins of manganese oxide forming a zone of diffuse mineralization in a brecciated limestone interbedded with quartzite. The average manganese content is about 5 percent, but in the past the ore was concentrated to yield a product containing more than 35 percent manganese, of which at least 1,500 tons was shipped. The silica content of the ore when concentrated is less than 5 percent. Smaller deposits of the same type are the Paddy Faulkner and Giant Chief in Riverside County.

### Replacement Deposits

Replacement deposits of several types are found in California, but most of them are small or of low grade. A deposit near the crest of the Sierra Nevada (Agnew Meadows deposit in Madera County) was formed by selective replacement of metavolcanic flows and tuffs for about 10 feet on either side of fissures. The replacement affected only two or three beds each about 3 feet thick. One bed has been converted principally to rhodonite, another to fine-grained rhodochrosite, and a third to hematite. Only two deposits of this type are known.

In Shasta County a siliceous porphyry adjacent to a fissure zone has been replaced by red jasper and by manganese oxides, forming a low-grade oxide deposit that contains from 15 to 20 percent of manganese (Shasta Copper deposit). About 1,000 tons of ore containing 27 percent of manganese was mined from this deposit during the first World War. The ore was high in silica and was used for making silico-manganese.

In Kern County a limestone is reported to have been partly replaced by oxide (Apache deposit). At Altamont Pass in Alameda County, fragments of limestone, apparently from a conglomerate of Cretaceous age, have been replaced by manganese oxide and are strewn about in the deep soil (Dyer deposit). The pebbles contain, on the average, about 30 percent of manganese, but they constitute less than 1 percent of the soil. The limestone seems to have been replaced before it was deposited in the conglomerate, for the conglomerate in general is not stained with oxide.

Some unusual deposits occur in Tertiary tuffaceous limestone interbedded with sandstone and volcanic breccia in the Whipple Mountains, west of Lake Havasu (Monument King and Moulton deposits, San Bernardino County). Lenticular bodies of manganese oxide and hematite associated with jasper occur more or less paralleling the bedding of the limestone. Many of the manganese orebodies are surrounded by crusts of hematite. These deposits may have formed by replacement of limestone, although they have also been interpreted as bedded deposits.

### Superficial Deposits

Manganese occurs in superficial deposits of several different types, but most of these deposits are so small and so low in grade that they are hardly more than curiosities. In the Sierra Nevada, low-grade concentrations of oxide are found in lateritic soil beneath Tertiary lava (Big Guleh and Eagle's Head deposits, Amador County). In Tuolumne County manganese oxide forms a superficial residue on limestone (Schoettgen deposit). Chert breccia cemented with manganese oxide occurs in Placer County (Lloyd deposit), but this deposit contains less than 10 percent of manganese and has not been developed. On the Hearst Ranch, San Luis Obispo County, manganese deposits of two peculiar types are found (Red Rock and Marmolejo Creek deposits). One (Red Rock) consists of nodules up to 5 feet in diameter. The nodules are residual concentrations from serpentine, which occurs in this region, but their source is not definitely known. They contain



about 35 percent manganese. The other, which is on Marmolejo Creek, consists of calcite boulders, up to 5 feet in diameter, in which manganese oxide is disseminated. The manganese content is estimated to be about 3 percent. No ore has been found in place nearby, but the boulders cannot be far from their source. Another type of residual deposit is found in Santa Barbara County, where residual boulders of manganese oxide presumably derived from nearby Franciscan rocks rest upon Tertiary conglomerate (Morey deposit).

#### Deposits of Manganiferous Iron Ore

Manganiferous iron deposits of several types are found in California. At various places in Napa (Adams and Westendorf, and Blue Monday deposits), Lake (Rattlesnake and Black Powder deposits), and Mendocino (Thatcher Creek deposit) Counties, Franciscan chert adjacent to greenstone contains large bodies of manganiferous iron ore. The manganese content of deposits of this type is generally less than 10 percent, though the iron content may be as high as 60 percent. Some of these bodies contain several thousand tons of ore, but their manganese content is so low that they are of little value. Similar deposits are found in the older rocks in Trinity County, near Hayfork (Arrowhead and Dry Lake deposits). Bodies of the same type occur in the Sierra Nevada in metamorphosed chert (Paine Bros. deposit, Nevada County, Alexander deposit, Amador County, and Cole deposit, Tulare County) and in Calaveras schist (Cave City deposit, Calaveras County).

Certain deposits of manganiferous iron ore in the Franciscan formation on Usal Creek, in Mendocino County (Usal deposit) are of outstanding geological interest, though not promising as an economic resource. Chert, the most usual country rock for manganese deposits in the Franciscan, is not found in this region, but lenticular bodies of fine-grained limestone, 1 foot to 50 feet thick and from 3 feet to about 200 feet long, have here been selectively replaced by manganiferous iron oxide. The limestone is intimately associated with altered basic lavas, tuffs, and intrusive rocks. The limestone rests upon bodies of greenstone that apparently represent lava flows, and in places it is cut by greenstone that is clearly of intrusive origin. The limestone may be mineralized for a distance of 1 to 5 feet from the intrusive contact. The ore near the contact is black, dense, and splintery. Most of it contains from 10 to 25 percent of manganese and from 25 to 35 percent of iron. The limestone away from the mineralized zone is stained pink with iron oxide, and flakes of specularite have been developed along fracture planes. The limestone lenses are scattered, and even though they are found at intervals over an area of several square miles, the aggregate tonnage of ore contained in them is small.



Table 1—Classification of California Manganese Deposits

Character of deposit	Geologic environment	Primary minerals	Name of deposit	County
Bedded deposits in chert, showing little or no metamorphism	Franciscan formation	Rhodochrosite	Jones	Santa Clara
			Buekeye	Stanislaus
	Franciscan formation	Rhodochrosite and bementite		Generally throughout the Coast Ranges
	Franciscan formation	Rhodochrosite and neotocite	Charles Mountain	Humboldt
	Franciscan formation	Neotocite	Johe Ranch	San Luis Obispo
	Franciscan formation	Rhodochrosite, bementite, and hausmannite	Blue Jay	Trinity
			Staneuch	San Luis Obispo
	Franciscan formation	Inesite	Hale Creek	Trinity
	Franciscan formation	Braunite	Fort Seward	Humboldt
	Franciscan formation	Recrystallized manganiferous chert	Cedar Tree	Santa Clara
			White	Trinity
	Franciscan formation and pre-Franciscan chert	Manganiferous chert	Manganese 1, 2, 3, 4	Siskiyou
			Carr, Snowcamp	Trinity
Slightly metamorphosed bedded deposits in chert	Amador group	Rhodochrosite and bementite	Big Little Bear, Kellogg	Calaveras
			Caldwell	Mariposa
	Amador group	Rhodochrosite, bementite, and rhodonite	Hughes	Tuolumne
	Pre-Franciscan chert associated with basic plutonic intrusions	Rhodochrosite, bementite, and rhodonite	Spider, Manganese Queen, Lucky Bill	Trinity
			Goat Camp	Shasta
	Amador group	Rhodonite	Custer, Du Frene	Amador
			Callahan, Daniels, Gorham	Calaveras
	Triassic (?) slates (Elsinore metamorphic series)	Rhodonite	Beal-McClellan, Elsinore	Riverside
Distinctly metamorphosed bedded deposits in recrystallized chert (fine-grained quartzite). May be massive-bedded (many localities) or thin-bedded, often with slaty partings (Victor and Nigger Hill deposits, Shasta County; Binet deposit, Butte County; Mayland deposit, Siskiyou County; Germolis and Lubanko deposits, Amador County; Jones Ranch deposit, Calaveras County)	Calaveras series	Rhodonite	Bean, Clemens	Yuba
			Ryan	Nevada
			Gold Hill, Pettigrew-Stafford lease, Randel No. 1	Placer
			David, Martinez Gold	El Dorado
			Jones, Pereni, Peyton	Amador
			Pedro	Tuolumne
			Donnelly, Strickland	Mariposa
	In metamorphics of uncertain age	Rhodonite	McMurtry	Fresno
			Gill Ranch	Tulare
			O. K.	Kern
			Rhodonite	Siskiyou
			Sam Brown	Humboldt
	In Pelona schist (pre-Cambrian)	Rhodonite	Black Bros., Purple Sage, Red Feather	Los Angeles

(Continued on next page)

Table 1—Classification of California Manganese Deposits—Continued

Character of deposit	Geologic environment	Primary minerals	Name of deposit	County
(Continued from preceding page) Distinctly metamorphosed bedded deposits in recrystallized chert (fine-grained quartzite). May be massive-bedded (many localities) or thin-bedded, often with slaty partings (Victor and Nigger Hill deposits, Shasta County; Binet deposit, Butte County; Mayland deposit, Siskiyou County; Germolis and Lubanko deposits, Amador County; Jose's Ranch deposit, Calaveras County)	Calaveras series	Rhodonite and spessartite	Airola, Harrington, Hauselt, Pescia	Calaveras
			Wonder	Tuolumne
			Surprise	Mariposa
	In metamorphics of uncertain age	Rhodonite and spessartite	Stewart and Nuss	Madera
			Harper	Fresno
			Culbert, Manganese Queen	Kern
			Ruby	San Diego
	Calaveras series	Spessartite	Carley, Fortner Ranch, Soapstone	Calaveras
			Windeler	Tuolumne
	Calaveras series	Rhodochrosite	Germolis, Lubanko(?)	Amador
Bedded wad deposits	In metamorphics of uncertain age	Rhodochrosite	Oro Fino No. 2	Siskiyou
	In Tertiary lake beds (?)	Wad	War Baby	Inyo
			Owls Spring	San Bernardino
	Fanglomerate impregnated with manganese oxides; probably like fissure deposits in origin		Orehard, Dunbar	San Bernardino
Fissure deposits	In volcanics		Taylor	Mono
			Black Raven, Northrup, Logan, Lee Yim, Big Reef	San Bernardino
			Arlington	Riverside
			Lugo	Imperial
	In fanglomerate		New Deal, Stewart	San Bernardino
			Chocolate Drop group, Whedon, War Manganese	Imperial
	In granitic rocks		New Deal (part), Black Mountain	San Bernardino
			Whedon (part)	Imperial
	Between granite and limestone		Black Stone	San Bernardino
	In limestone		Langdon, Mountaineer, Paddy Faulkner, Giant Chief	Riverside
Replacement deposits (replacement may also occur in the fissure deposits listed above)	Metavolcanics adjacent to fissures		Agnew Meadows	Madera
	Acid porphyry adjacent to red jasper		Shasta Copper	Shasta
	Limestone (see also manganeseiferous iron ore deposits below—Usal deposit, Mendocino Co.)		Apache	Kern
	Limestone fragments in Cretaceous conglomerate		Dyer	Alameda
	Tuffaceous limestone; manganese ore associated with hematite and jasper. Origin uncertain.		Monument King, Moulton	San Bernardino

Table 1—Classification of California Manganese Deposits—Continued

Character of deposit	Geologic environment	Primary minerals	Name of deposit	County
Superficial deposits	In lateritic soil below Tertiary lavas		Big Gulch, Eagle's Head	Amador
	As superficial residue on limestone		Schoettgen	Tuolumne
	As cement in a chert breccia		Lloyd	Placer
	Nodules in serpentine		Hearst Ranch-Red Rock	San Luis Obispo
	Boulders of calcite, with disseminated manganese oxide		Hearst Ranch-Marmolejo Creek	San Luis Obispo
	Boulders in gravel, derived from Franciscan		Morey	Santa Barbara
Manganiferous iron ore deposits	In Franciscan chert in serpentine or greenstone areas		Adams and Westendorf, Blue Monday	Napa
			Rattlesnake, Black Powder	Lake
			Thatcher Creek	Mendocino
	In pre-Franciscan chert in serpentine or greenstone areas		Arrowhead Dry Lake	Trinity
	In metamorphosed chert		Paine Bros.	Nevada
			Alexander	Amador
			Cave City	Calaveras
			Cole	Tulare
	Replacing limestone, associated with greenstone in Franciscan formation		Usal	Mendocino

### PRODUCTION

Figures on the production of the manganese mines of California were compiled from all available sources. These include records on file in the Geological Survey and Bureau of Mines, of the United States Department of the Interior, and in the California State Division of Mines; a manuscript report by George D. Louderback and associates prepared in 1917 and 1918; a manuscript report of Robert S. Kroger; Bulletin 76 of California Division of Mines, published in 1918; and information supplied by mine operators. The production from individual mines is not given in this report, but the properties are divided into four categories: (A) those that have produced 1,000 tons or more; (B) those that have produced 150 to 999 tons; (C) those that have produced 1 to 149 tons; and (D) those that have produced no ore. The actual production for each county is given, however, in Table 2.

The history of manganese mining in California goes back to 1867, when the Ladd mine, near Tracy in San Joaquin County, was first opened. According to records published in the Mineral Resources of the Geological Survey the total production from California prior to 1914 was 13,000 tons, a large part of which presumably came from the Ladd mine. A few hundred tons was reported each year up to 1902, which is about the time the Ladd mine is said to have been abandoned,

Table 2—Production of Manganese From California Arranged by Counties

County	Number of deposits	Number of producing mines	Production to the end of 1941, tons	Chief minerals in primary ore
Alameda	31	16	4,604	Carbonate and bementite
Amador	15	6	585	Rhodonite
Butte	10	3	305	Rhodonite
Calaveras	17	0	0	Rhodonite and spessartite
Colusa	3	0	0	Carbonate and bementite
Contra Costa	1	1	200	Carbonate and bementite
Del Norte	2	0	0	Carbonate and bementite
El Dorado	6	0	0	Rhodonite
Fresno	8	1	33	Rhodonite
Glenn	10	4	237	Carbonate and bementite
Humboldt	15	3	1,846	Carbonate and bementite
Imperial	11	5	4,545	Oxide in fissure deposits
Inyo	11	0	0	Oxide in fissure deposits
Kern	10	1	23	Rhodonite
Lake	33	4	462	Manganiferous iron oxide
Los Angeles	4	1	168	Rhodonite
Madera	6	0	0	Rhodonite and spessartite
Marin	6	1	0 <sup>a</sup>	Carbonate and bementite
Mariposa	7	1	250	Rhodonite and spessartite
Mendocino	61	17	9,837	Carbonate and bementite
Merced	1	0	0	Carbonate and bementite
Mono	6	1	0 <sup>b</sup>	Oxide in fissure deposits
Monterey	3	0	0	Carbonate and bementite
Napa	14	1	302	Carbonate and bementite
Nevada	15	3	185	Rhodonite
Placer	7	2	100	Rhodonite
Plumas	15	6	3,948	Mainly braunite
Riverside	12	3	6,754	Oxide in fissure deposits
San Benito	7	2	246	Carbonate and bementite
San Bernardino	21	9	1,563	Oxide in fissure deposits
San Diego	9	0	0	Miscellaneous
San Joaquin	7	3	32,250	Carbonate and bementite
San Luis Obispo	29	9	4,778	Carbonate and bementite
Santa Barbara	3	0	0	Carbonate and bementite
Santa Clara	45	28	3,148	Carbonate and bementite
Shasta	8	2	1,000	Miscellaneous
Siskiyou	31	4	50	Rhodonite
Sonoma	18	4	1,499	Carbonate and bementite
Stanislaus	28	16	17,690	Carbonate and bementite
Tehama	7	0	0	Carbonate and bementite
Trinity	105	9	138	Carbonate and rhodonite
Tulare	5	0	0	Rhodonite
Tuolumne	10	2	45	Rhodonite and spessartite
Yuba	2	0	0	Rhodonite
Totals	675	168	96,791	

<sup>a</sup> Small production; amount unknown.<sup>b</sup> No production prior to 1942.

and for each of the next 11 years the annual production was less than 100 tons. Production was stimulated by the advent of the first World War, and some 60,000 tons was mined between 1914 and 1920, the largest annual production being 24,000 tons in 1918. Between 1921 and 1940 the total production was only 4,000 tons. The coming of the present war has again stimulated production, and the manganese resources of the State are now being actively prospected and exploited. According to the records published by the Geological Survey and the Bureau of Mines, the total production of the State to the end of 1940 has been about 80,000 tons.<sup>3</sup>

In the course of the work on which the present report is based, the total production computed by adding the production of individual deposits, is about 95,000 tons. The difference of 15,000 tons is due

<sup>3</sup> Mineral Resources U. S., 1922, p. 587; idem, 1924, p. 92; idem, 1926, p. 143; idem, 1929, p. 209; idem, 1930, p. 270.

Minerals Yearbook, 1935, p. 470; idem, 1940, p. 577.

partly to the fact that the estimates given here cover a period ending one year later, but mainly to a higher estimate than that published of the production from the Ladd mine. The size of the stopes and dumps of this mine indicates a total production of about 30,000 tons. As the mine is reliably reported to have produced some 10,000 tons between 1914 and 1918, a total production of 30,000 tons would imply a production of 20,000 tons prior to 1914, whereas the total production for the state before 1914 is given as only 13,000 tons. This discrepancy might mean that the estimate of 30,000 tons for the production of the Ladd mine is 10,000 to 15,000 tons too high; it seems more probable, however, as this mine was operated mainly before accurate statistics of production were kept, that its early production was not fully recorded. Minor errors may also have been made with regard to the production from some of the other mines, because of transfer of leases and consolidation of properties. It is especially difficult to determine the production from individual mines that have been operated jointly. The production, moreover, from some mines producing ore that contains less than 35 percent manganese may not have been included with the published production, which refers mainly to ore of higher grade.

The distribution of production to the end of 1941, by counties, as determined from the estimated production of the individual mines, is given in the accompanying table. Manganese has been produced from nearly 170 properties in 31 counties—slightly over half the total number of counties in the State. The leading county is San Joaquin, which has produced more than 32,000 tons, almost all of it from the Ladd mine. Stanislaus County is the second largest producer, having produced about 18,000 tons to the end of 1941, most of it from the Buckeye mine, which is the second largest manganese mine in the State. Following these counties in order are Mendocino, 10,000 tons; Riverside, 6,750 tons; San Luis Obispo, Alameda, and Imperial, 4,500 tons each; Plumas, 4,000 tons; Santa Clara, 3,000 tons; Humboldt, 2,000 tons; San Bernardino and Sonoma, 1,500 tons each; and Shasta, 1,000 tons. No other county has produced more than 1,000 tons.

#### AIDS TO PROSPECTING

There probably are undiscovered manganese deposits in California, and, as manganese is a strategic mineral, the finding of deposits that could be mined would be a public service. Information that might be helpful in prospecting for manganese is therefore presented in the following pages.

##### Ore Minerals

Manganese outcrops can almost always be recognized by their black color, for all manganese minerals weather to black oxides. In many places the oxides at the surface are soft and sooty and leave black smudges on the hands when touched; in other places, however, they are hard, flintlike, and steel-gray to black. The unweathered minerals below the surface are of various colors; all of them, however, are heavy, and the grade of manganese ore can sometimes be roughly estimated by "hefting" a piece of it. These two facts, then, are of prime importance: the manganese minerals, when in compact form, are heavier than ordinary rocks; and they are all black when weathered.

The main primary mineral in the Coast Ranges of California is rhodochrosite (manganese carbonate). It here occurs most commonly as fine-grained white or gray rock, looking much like dirty rock sugar, but much harder, though it can be scratched with a knife. This type of rhodochrosite is dense and tough, being difficult to break with a sledge hammer. In places it is cut by veins of typical pink rhodochrosite. Rhodochrosite commonly contains somewhat less than 45 percent of manganese.

Rhodonite, manganese silicate, is the main primary mineral along the west side of the Sierra Nevada. It is red in color, and can just barely be scratched with a knife. In places it is not easily distinguishable from the more desirable mineral rhodochrosite, but several differences between the two minerals can be perceived when they are carefully compared. Rhodonite crystals have a bladed habit, which contrasts with the granular habit of rhodochrosite. Much rhodonite, also, has a purplish-red color that is readily recognizable with a little practice, and rhodochrosite is never purplish. The luster of rhodonite is vitreous or glassy, whereas the luster of rhodochrosite is soft and much like that of slightly greasy lump sugar. Effervescence with acid is not always a safe criterion, because in some deposits calcite or some other carbonate fills interstices between rhodonite crystals and effervesces slightly when acid is applied, just as typical rhodochrosite does. The manganese content of pure rhodonite is about 41 percent, but few rhodonite deposits in California contain over 38 percent of manganese.

Bementite, a hydrous manganese silicate of variable composition, is found with both rhodochrosite and rhodonite, and in some deposits is the main manganese mineral. Bementite deposits commonly contain from 15 to 40 percent manganese. This mineral varies in color from dark honey-yellow or reddish brown to straw color. When coarsely crystalline it is bladed, but most California bementite is finely crystalline and has a waxy luster, which is highly characteristic but which inexperienced persons may have difficulty in recognizing. The best way to find bementite is to look for weathered fragments of a waxy yellow or brown rock that cannot be scratched with a knife and that grades outward into black oxide.

Neotocite is a glassy, shiny, black, dark-red or dark-yellow mineral which is found in manganese deposits at a few widely scattered places in the Coast Ranges. It is a manganese opal or hydrous silicate containing some 15 to 35 percent of manganese. It does not form any large orebodies.

Spessartite, the manganese garnet, usually occurs in small, brown, dodecahedral crystals. It is the primary mineral in many of the Sierra Nevada deposits, either alone or accompanied by rhodonite. It commonly gives rise to a friable, granular, brownish-black oxide ore which in the Sierra Nevada is usually shallow. Spessartite in itself has no value as a source of manganese.

Hausmannite is found at several places in the Coast Ranges, mainly in San Luis Obispo County (Staneuch deposit); it is also found in Stanislaus County at the Buckeye mine, and in the upper Mad River Valley, in Trinity County, principally at the Blue Jay mine. The better grades of hausmannite ore in the Blue Jay mine contain about 56 percent manganese. The California hausmannite is dark reddish

brown in color and very fine-grained. It looks much like bementite, except that bementite has a waxy luster whereas hausmannite is earthy. The mineral is not very easy to recognize, and chemical analysis or X-ray pictures are the best means of identifying it with certainty. Even without these, however, experience will enable one to distinguish it from the other manganese minerals with which it is likely to be associated. The presence of manganese in a rock that contains hausmannite becomes apparent even without assays within a few weeks, for hausmannite soon turns black when exposed to the air, and then the rock containing it looks like any other oxide ore. Operators in the three counties mentioned should not throw away dark reddish-brown mineral without first assaying representative samples to determine the manganese content.

Braunite is a hard, dense, black, splintery mineral with a dull or subvitreous luster. It has been identified with certainty in two mines—the Braito mine in Plumas County, and the Fort Seward mine in Humboldt County. The California braunite ores contain 45 to 50 percent of manganese, and 12 to 15 percent of silica. The best test for braunite is to dissolve it in muriatic acid and evaporate the acid, when a gelatinous mass will be left. Some bementite or neotocite also will gelatinize, but these minerals can be distinguished from braunite by their yellow or brown color and glassy or waxy luster.

Several manganese oxides are found in California, but they cannot readily be distinguished without X-ray pictures. Oxide found in hard, black, shiny aggregates of lumpy or botryoidal outline is usually called psilomelane, and soft, black oxide, which may or may not be coarsely crystalline, is usually called pyrolusite. The black oxides, when pure, contain 63 to 68 percent of manganese, but as mined they mostly contain less than 60 percent.

Two minerals which may occur in the same geologic setting as manganese oxide and are most apt to be mistaken for it are the iron oxides, hematite and limonite. Both are sometimes nearly black in color, and hematite is even heavier than manganese oxide. They may be distinguished, however, by scratching with a knife or pick to determine the streak or color of the powdered mineral. The streak of hematite is brick red or reddish brown, that of limonite is yellowish brown, whereas the manganese oxides possess a black or dark brownish-black streak.

One misleading characteristic of manganese oxide is its tendency to pervade fractures and joints in a rock, so that a broken fragment may appear to be solid manganese oxide when actually it is merely stained with this material. These films are particularly common in chert, but they also occur in greenstone and other rocks. It is necessary to break the rock until a fresh surface is reached, in order to reveal its true nature. The lighter "heft" of a rock merely stained with manganese oxide also serves to distinguish it from solid ore.

#### Occurrence

Modes of occurrence of manganese minerals in California are summarized in table 1. From the many details there given, the fact emerges that the great majority of the deposits occur in one of three ways: (A) in chert of the Franciscan formation, exposed in the Coast

Ranges; (B) in recrystallized chert or fine-grained quartzite interbedded with more or less metamorphosed rocks older than the Franciscan; and (C) in and adjacent to fissures, mostly in volcanic rocks and fanglomerates.

New discoveries of manganese ore are most likely to be made in regions where manganese deposits have already been found, and it is in such regions, also, that the prospector can become acquainted with the character of the outcrops and so learn what to look for.

Franciscan cherts containing manganese deposits (group A) are found mainly in four parts of the Coast Ranges, which are, from north to south: (1) the Mad River Valley in the western part of Trinity County; (2) east-central Mendocino County and the adjoining part of Lake County; (3) the mountains southwest and south of Tracy, in San Joaquin, Alameda, Santa Clara, and Stanislaus Counties; and (4) the western part of San Luis Obispo County. Chert of the Franciscan formation occurs in other localities, but most of the manganese deposits in that rock are in the regions just outlined.

Deposits in recrystallized chert or fine-grained quartzite interbedded with more or less metamorphosed rocks older than the Franciscan (group B) are found mainly in three areas: Siskiyou County, eastern Trinity County, and scattered localities on the western slope of the Sierra Nevada from Plumas County at the north to Kern County at the south.

Deposits in and adjacent to fissures (group C) are most common in volcanic rocks and fanglomerate in southern Inyo County, San Bernardino County, and the eastern parts of Riverside and Imperial Counties.

Deposits of groups A and B belong essentially to a single class, differing mainly by reason of the fact that the deposits in group B are older and are more altered than those of group A. All of them are interbedded with a certain kind of siliceous rocks, and hence are to be looked for where these rocks are found. In the Franciscan formation the usual country rock of the deposits is chert, which is very fine-grained. Most of the chert is red and thin-bedded, but that enclosing manganese deposits is mostly whitish and thick-bedded. In the older formations of the Sierra Nevada these originally cherty rocks are largely recrystallized so as to resemble quartzites, but in general they show the thin bedding that is characteristic of the Franciscan cherts.

Thin-bedded siliceous rocks are thus the first thing to look for in prospecting for these manganese deposits of groups A and B, but float of manganese oxide should also be looked for. The ore of these deposits ordinarily contains enough silica—often recognizable as forming irregular white patches—to stand much rolling along stream beds. A prospector should therefore walk the streams in search of boulders of manganese ore, and trace them to their source if any are found.

Deposits of groups A and B are similar in form. As already stated, the general form of the larger ones is that of a pancake, having a blunt edge and an outline that may be nearly circular but that is more usually an ellipse; the ellipse is ordinarily at least half as broad as it is long. These larger bodies are most worth looking for, not only because of their size but because the ore in them is of higher grade, on the average, than that in the smaller bodies.



An outcrop of such a deposit, tilted up steeply as it usually is, is likely to be long and narrow. If a great number of cases could be taken into account, the average situation would be as if a circular disc-like body were intersected by the surface along a line through its center—that is, as if half the disc had been eroded away and a semi-circular piece of it remained in the ground. In this average case, the maximum depth from the surface to the lowest part of the edge would obviously be half the outcrop length, though the average depth would be only about two-fifths of the outcrop length.

In any specific case, of course, the maximum depth might be much less or much greater than half the outcrop length. The depth would be greater in a place where only the upper edge of a large bannock of good ore was exposed. In such a case, on digging downward, the orebody would be found to increase in length, and, because of the usual bluntness of its edge, it might increase rapidly in width also to a depth of 10 or 20 feet. But this enlargement is likely to be found, if it occurs at all, within 20 feet or so of the surface; if, therefore, the orebody is small at the outcrop and remains so to a depth of 20 feet or more, it is unlikely that much ore will be found by going deep. A decrease in size downward would tend to indicate that the bottom edge of an orebody was being approached.

Downward increase in quality as well as size would also be a good sign. If the outcrop represents the upper edge of an orebody, the ore at the surface might be the lean, "stockwork" ore that often surrounds a large mass of good ore; and in that case an improvement in the quality of the ore would probably become apparent at a moderate depth.

Many of the Franciscan orebodies are hard, flinty, massive, and black at the surface of the ground but grade within a few feet of the surface into soft, sooty, earthy ore, which is easily mined with pick and shovel. Prospectors should not be deterred, therefore, from attempting to develop these dense hard outcrops; but if they are still dense and hard at a depth of 15 feet, the chances are they are of low grade throughout and will not get better with depth.

Oxidation usually increases the percentage of manganese in the deposits of groups A and B, so that, other things being equal, those deposits are most valuable in which oxidation has gone deepest. As already pointed out, oxidation generally penetrates to the greatest depth in rounded hills, in country where erosion is not proceeding rapidly, and it extends to lesser depths under the valley floors in that same sort of country. It goes, on the average, hardly half as deep in rugged country like that of northern California and the Sierra Nevada as in the central and southern Coast Ranges.

Some minerals are more readily oxidized than others: of the two most abundant primary minerals, rhodochrosite is more oxidizable than rhodonite, little of which is oxidized to a depth of more than 25 feet. Rhodochrosite predominates in the Franciscan deposits proper (group A), and rhodonite in the older, more or less metamorphosed deposits of the Sierra Nevada (group B).

The Franciscan manganese deposits are cut by numerous faults, and in many places the faults have caused the structure to be so complicated that the orebodies are followed with difficulty; but in other areas, notably the region west of Tracy, most of the faults have dis-

placements of less than 50 feet. On most of the faults there has been some horizontal movement, and ordinarily the block at the left of an observer looking along the fault has been moved, relatively speaking, away from the observer.

Of the clues that might lead to discovery of deposits in siliceous bedded rocks (groups A and B), hardly any would be useful in searching for deposits in other rocks (group C). One clue, however, applies to these as to all others: the manganese ore at the outcrop is largely black oxide. In the deposits of group C, indeed, the primary ore is likely to be oxide down to the bottom of the orebodies.

A special case is presented by the "black calcite" deposits. In these the manganese mineral is indeed oxide, and the outcrop material consists essentially of oxide alone, but this grades downward into calcite impregnated with oxide. The black calcite has a much lower manganese content than the purer oxide ore above, from which the calcium carbonate has been leached out.

The fissure deposits are of special interest. Ore-bearing fissures may be as much as a mile long, but the ore is concentrated in shoots, which range from a few feet to 500 feet in length, from 10 to more than a hundred feet in depth, and from a few inches to more than 10 feet in width. The best way to prospect these deposits is to sink shafts in the widest and richest parts of the outcrops. If the ore does not attain a minable width and a commercial grade within 15 or 20 feet, it is not likely to be worth following to a greater depth.

In bedded deposits in fanglomerate and the like, the manganese oxide is in the impure form known as wad, which is generally of low grade. Wad is generally of potential commercial importance only when present in extremely large deposits of better than average grade, from which large-scale open-cut mining may yield material of high enough grade and large enough tonnage to justify elaborate and expensive metallurgical treatment. A few deposits, in other states, that consist mainly of wad, contain certain nodules of higher-grade oxide that can be concentrated by log-washing, and such deposits may be worked on a small scale.

## DISTRIBUTION OF MANGANESE DEPOSITS IN CALIFORNIA

### Alameda County

Manganese is reported from about 30 localities in Alameda County. All of these, except one, are in the Arroyo Mocho Valley or adjacent territory, southeast of Livermore, and are typical Franciscan deposits in chert. The one exception is on the Dyer property in Altamont Pass, where limestone fragments partly replaced by manganese oxide are found in deep soil, of which they constitute less than 1 percent. They range up to 2 inches in length, and seem to be derived from a Cretaceous conglomerate. They contain about 30 percent manganese.

The Arroyo Mocho Valley has been an important source of manganese, having yielded 4,600 tons from 16 properties. The principal mines have been the Camp 9, the Man Ridge, the Section 14, the Taylor-Pitcher, the Bartlett, the Graves, the Black Jack, the Nelson or Bailey, and the Corral Hollow. No production has been reported during the present war, and only a few deposits are now being prospected. The Man Ridge, the Nelson or Bailey, and the Section 14 are the only deposits visited that were found to have been worked recently.

### Amador County

Manganese is known to occur in Amador County at 15 places, rather uniformly distributed through the western part of the county. The production has been about 600 tons, mainly from the Stirnaman and the Ruhser and Hubberty properties. The Stirnaman and Lubanko deposits have produced ore during the present war.

The ore found in Amador County is of several types. Most of the deposits consist of segregations or disseminations of oxide and rhodonite in recrystallized chert of the Calaveras series, which occurs east of the Mother Lode. Two deposits, the Big Gulch and the Eagle's Head, are concentrations of low-grade manganese oxide in lateritic soils beneath Tertiary lava beds. Two others, the Custer and the Du Frene, consist of layers of oxide in slightly recrystallized chert associated with basic metavolcanic rocks of the Amador group, which occurs west of the Mother Lode. The primary ore in these deposits is probably rhodonite. One low-grade deposit, the Alexander, contains a bed of manganiferous and ferruginous chert in slates. Two deposits, the Germolis or Rodonick and Lubanko consist of lenses of manganese oxide, up to 3 feet in thickness, in recrystallized massive chert. The oxide seems to grade downward into rhodochrosite. In both deposits the massive recrystallized chert is enclosed in metamorphosed thin-bedded chert with slaty partings, which contain some low-grade manganese oxide. Similar rocks enclose high-grade oxide ore in the Stirnaman deposit, in which the primary ore has not yet been reached at a depth of 25 feet.

### Butte County

Ten manganese deposits are known to occur in Butte County. All but two of these are situated in the eastern tip of the county, near Clipper Mills. The Josephine prospect lies in the center of the county, near Yankee Hill, and the Smithwick and Noble property is located in the northern part of the county, near Butte Meadows. Past production from the county amounts to 305 tons.

The manganese in Butte County is found in fine-grained quartzite, interbedded with dark slate, phyllite, and sericite schist. The quartzite looks very much like metamorphosed chert, and in some deposits, such as the Binet, it alternates with slate in a way that recalls the rhythmic bedding of the Franciscan chert. Most of the deposits in Butte County are low-grade and consist of thin veins of oxide or of oxide disseminated in chert, but the orebody at the Bear Canyon mine has a maximum thickness of 4 feet. The primary mineral is probably rhodonite.

### Calaveras County

Manganese is reported from 16 places in Calaveras County, all in its southern half, but the county has not yet produced any ore. The Airola property has been developed during the present war and will probably produce some ore in the future. Most of the deposits consist of oxide, rhodonite, and spessartite segregations in the recrystallized chert that is interbedded with schist of the Calaveras series east of the Mother Lode. Little spessartite has been found north of Calaveras County, but the mineral is common farther south. Properties containing deposits of the prevailing type are the Airola, the Harrington, and the

Hauselt. In some deposits the only primary mineral seems to be spessartite, which is disseminated in recrystallized chert or fine-grained quartzite (Carley, Fortner Ranch, and Zurcher deposits). The average manganese content of such deposits is not over 15 percent. In other deposits, in chert in metavolcanics of the Amador group west of the Mother Lode, the primary mineral is rhodonite. Examples of this type are the Callahan, the Daniels, and the Gorham. Deposits in which the primary ore consists principally of rhodochrosite and manganiferous chert are also exemplified in the Amador group. Bementite lenses and segregations occur in more or less massive chert on the Big Little Bear and Kellogg properties. One deposit, on the Cave City or Thomas Brothers claim, consists of pockets of manganiferous iron oxide in sericite schist of the Calaveras series; the manganese content of this deposit is less than 10 percent—about 7 percent according to some assays. One deposit, on the Joses property, consists of thin stringers or veins of oxide in thin-bedded recrystallized chert in the Calaveras schist.

#### Colusa County

Colusa County is known to contain three manganese deposits. One, the Rathbun, is in the northwestern part of the county, near the deposits in southern Glenn County; the other two are about 10 miles to the southeast, near the boundary with Lake County. All are typical Franciscan deposits of low to medium grade in chert. No ore has yet been produced from the county.

#### Contra Costa County

A small deposit of Franciscan red chert on Red Rock Island in San Francisco Bay, near Richmond, was mined for manganese in 1867, and it is said that “one schooner full”—which might be about 200 tons—was shipped to England. The grade of this ore is unknown. The deposit seemingly has not been worked since then, and no other manganese deposits have been reported to occur in the county.

#### Del Norte County

Two manganese deposits in Del Norte County are on record, one on the Middle Fork, the other on the North Fork, of Smith River. According to the Geologic Map of California, these deposits are in Jurassic rocks and are therefore presumably similar to Franciscan deposits. No production has been reported from Del Norte County.

#### El Dorado County

Six known deposits of manganese occur in the western part of El Dorado County but they have not yet produced any ore. In most of the deposits the ore consists of disseminated oxide or rhodonite in recrystallized chert, interbedded with schists of the Calaveras series. In one deposit, the Alderson, manganese oxide is reported to occur as a cement in arkosic sandstone interbedded with Tertiary volcanics. The Mocettini deposit consists of manganese stains in greenstone. The grade in both of these deposits is relatively low.

### Fresno County

Manganese is reported from eight places in Fresno County. Six lie in a northwestward-trending belt that crosses the Kings River about 5 miles northeast of Piedra, in the east-central part of the county. These deposits are essentially in the projection of the strike of the deposits in Madera County to the north. They consist of segregations of rhodonite in recrystallized chert or quartzite interbedded with schist of the Calaveras type. One, the Harper deposit, contains spessartite. Two deposits are in Franciscan rocks in the Coast Ranges, at the southwestern edge of the county. One of these, the Sunset and Sunrise mine, is the only one that has produced manganese in the county.

### Glenn County

Glenn County is represented by ten deposits. Two of these, in the northwestern part of the county, consist of low-grade manganiferous chert in sericite schist. The others, in the southwest part of the county, are typical Franciscan orebodies in chert. Many of these deposits consist of low-grade manganiferous chert. The production from the county during the first World War was 237 tons, which came from the Black Diamond, the Rattlesnake, and the Levensaler and Speir Corporation properties. During the present war only one deposit, the K. B. No. 4, has produced ore.

### Humboldt County

Manganese is reported from 15 places in Humboldt County. Most of these are in the southeastern part of the county, near Alder Point, but one is near Arcata, 10 miles north of Eureka, and two are in the northeastern part of the county, in the Trinity River drainage basin. The production of manganese from the county has been 1,850 tons, about evenly distributed between three mines—the Fort Baker, the Charles Mountain, and the Fort Seward. The Charles Mountain mine is the only deposit which has produced ore during the present war.

The manganese ore in the county is found mainly in chert of the Franciscan formation. In the producing mines it consists of massive beds of oxide, presumably derived from rhodochrosite or bementite. At the Fort Seward mine, however, the primary ore contains braunite. The primary ore in the Charles Mountain deposit is carbonate, bementite, and neotocite. Two of the deposits, the Leaning Tree and the Sam Brown, lie in the belt of metamorphic rocks that follows the west side of the Trinity River Valley. The Leaning Tree deposit consists of manganese stains in a zone of sheared greenstone. The Sam Brown deposit is mainly composed of rhodonite in recrystallized chert and contains very little oxide.

### Imperial County

Manganese ore is reported from 11 places in Imperial County, all near the eastern border. It is found in three main areas: (A) the summit of the Palo Verde Mountains—the Lugo deposit; (B) the western edge of the Palo Verde Mountains—the Chocolate Drop deposits; (C) the Paymaster district, in the Barren Mountains—which

contains the Whedon and War Manganese deposits. The orebodies are all fissure deposits in Tertiary conglomerate or lavas, or in older granite. In the Paymaster region three main groups of fissures can be traced for nearly a mile. The ore is found in shoots, one of which is over 500 feet in length, 7 feet wide, and 60 feet in maximum depth. Most of the orebodies are from 2 to 3 feet in average thickness. The ore consists principally of hard manganese oxide that forms a cement around pebbles and rock fragments in brecciated conglomerate adjacent to the fissures. Soft manganese oxide, including manganite (?), also is present. In one deposit, the Black Hill (part of the Whedon), the ore is in fractured granite adjacent to fissures.

The production from the region to the end of 1941 has been about 4,500 tons, almost all of which is from the Paymaster<sup>4</sup> district. The Whedon is reported to have produced several hundred tons in 1942. The War Manganese and Chocolate Drop deposits have also produced some ore during the present war.

#### Inyo County

Eleven manganese deposits are known to occur in Inyo County, but no production of manganese from the county is reported. Most of the orebodies are fissure deposits in volcanic rocks. Manganese oxide has filled the interstices in breccias adjacent to fissures, and has also replaced the host rocks to some extent. The fissures can be traced for distances up to 2,000 feet, though the degree of mineralization varies along the strike. The ore zones may attain a width of 10 feet, but in most places they are less than 3 feet wide. The manganese content of the ore as mined is 25 to 30 percent. By analogy with fissure deposits in the country around Parker, Arizona, to the southeast, the oxide should be amenable to concentration. The most promising fissure deposits are in the Wingate Wash, at the north end of the Owls Head Mountains, near the southern border of the county.

#### Kern County

Manganese is reported from ten places in Kern County, most of which are in the desert, in the vicinity of Randsburg. One, the O. K. or Keough deposit, is in the Sierra Nevada along the South Fork of Kern River; another, the Snowy or Cuddy deposit, is in the Tehachapi Mountains northwest of Lebec. The production from Kern County has been 23 tons.

The deposits around Randsburg consist of rhodonite and oxide in massive quartzite or metamorphosed chert in quartz-mica schist. In one deposit, the O. K. or Keough, located in the Sierra Nevada, rhodonite forms coarse crystals as much as 3 inches in diameter. Another deposit, the Manganese Queen, contains spessartite in addition to rhodonite. The Snowy or Cuddy deposit in the Tehachapi Mountains, consists of a low-grade highly siliceous manganiferous rock enclosed in quartz-mica schist, which in turn forms a roof pendant in granitic rock. The nature of the primary ore is not known, but it probably is rhodonite. One small deposit, the Apache, is reported to be an oxide replacement in limestone.

<sup>4</sup> For additional information on the Paymaster deposits see Hadley, J. B., 42.

### Lake County

Lake County contains about 33 known manganese deposits, all in the Franciscan formation, distributed somewhat uniformly through the county. Most of them are low-grade siliceous oxide in chert. A few, such as the Black Powder and Rattlesnake, consist of manganimiferous iron oxide in chert associated with greenstone. Approximately 500 tons has been produced from the Phillips, the Middle Creek or Vann Ranch, Von Glahn and Gravelley Valley deposits. The Gravelley Valley is the only one to have produced during the present war. The ore in these mines was found in lenses of fairly high-grade oxide in chert. The thickness of the deposits ranges up to 4 feet.

### Los Angeles County

Four manganese deposits are reported from Los Angeles County. All of them lie in the northern part of the county, west of Palmdale, and they all consist of rhodonite in massive quartzite or recrystallized chert in the Pelona schist, of pre-Cambrian age. The Red Feather or La Frentz mine is the best example. Oxidation extends to a depth of 10 feet at some places in this mine but in general its depth is less. The average manganese content of the rhodonite ore is about 20 percent. The county has produced 168 tons, all during the first World War.

### Madera County

Six manganese deposits in Madera County are recorded, but no production has been reported. All but one of the deposits are located near Coarse Gold, in a northwestward-trending belt in the middle of the county, and consist of segregations of rhodonite and spessartite in massive recrystallized chert, which seems to form roof pendants in granodiorite. They contain relatively little oxide. One deposit, the Agnew Meadows deposit, lies at the northeast end of the county. It is a replacement deposit in metavolcanic dacitic or andesitic flows and tuffs, adjacent to fissures along which mineralizing solutions have risen. The volcanic rocks dip steeply, and the fissures along which the ore has risen also dip steeply but strike at right angles to the rocks. For a distance of approximately 10 or 15 feet on both sides of the fissures, two or three beds up to 5 feet in thickness have been replaced by rhodonite, rhodochrosite, and specular hematite. The ore may contain as much as 30 percent of manganese.

### Marin County

Six deposits are reported from Marin County—two in the southeastern part, near Sausalito, one near San Anselmo, one south of Novato, and the other two a short distance southwest of Petaluma, near the northern boundary of the county. All are typical Franciscan deposits in chert, of small size, with little high-grade ore in sight. No production is credited to the county in the accompanying table. Penrose (91, p. 489) stated that the Sausalito Point deposit produced a little manganese which was used for flux, but he gave no figures on tonnage. The Knutte deposit has become active during the present war and is likely to produce some ore.



### Mariposa County

Mariposa County is known to contain seven manganese deposits, the production from which has been 250 tons. The deposits form two groups, one west of the Mother Lode in the northwestern part of the county, near Coulterville, the other some 10 to 20 miles farther east, in the drainage basin of the Merced River. Those near Coulterville consist of oxide, carbonate, and bementite in slightly recrystallized well-bedded chert in metavolcanic rocks of the Amador group. The other group consists of oxide, rhodonite, and spessartite in quartzite or recrystallized chert interbedded with schist of the Calaveras series. Spessartite is present in only one deposit, the Surprise. Two mines, the Caldwell and the Kelm, are active at present.

### Mendocino County

Mendocino County has been one of the largest producers of manganese in California, and is known to contain 61 deposits of manganese ore. These are all in the Franciscan formation, and all of them except a group near Usal are in chert and lie in the eastern half of the county. The production prior to the present war has been about 10,000 tons, from 16 mines. About half of it has come from the Thomas mine, 15 miles north of Ukiah. The remainder has come principally from the South Thomas, the Wild Devil, Bevins-Busch, Nowlin, Brereton, and Foster Mountain mines. The Skaggs Springs mine is said to have produced 450 tons during the first World War. The location of this mine has not been ascertained, but its name suggests that it might be in Sonoma County. The eight other mines have produced less than 100 tons each. The Linser mine, near Harris at the north end of the county, is in a newly discovered deposit which is producing ore. The Foster Mountain is the only other mine in the county which is producing ore at present.

The only deposits not in chert form a group near Usal (Usal deposit), in the northwestern part of the county. Small lenses of limestone, intimately associated with greenstone in the Franciscan formation, have been replaced by mangiferous iron oxide. The ore contains from 10 to 25 percent manganese and 25 to 35 percent iron. Most of the lenses are small and the aggregate tonnage is not large.

The other deposits are typical Franciscan deposits. Many of them are of low grade and consist of mangiferous chert. One, the Thatcher Creek deposit, consists of low-grade mangiferous iron oxide in chert associated with greenstone. Several thousand tons of ore, containing less than 10 percent manganese and over 50 percent iron, are estimated to be present in this deposit. Other prospects, one of them being the Cooper prospect, contain considerable shiny neotocite.

The orebodies in the producing mines consist of lenses of oxide, which presumably are derived from carbonate or from mixtures of carbonate with bementite or mangiferous chert. The ore at the Thomas mine comes from a bed that is about 6 feet in average thickness and 600 feet in length, being one of the longest bodies of manganese ore in the Franciscan formation. The oxide ore may have been largely mined out, but a considerable tonnage of carbonate ore could probably be obtained if a market for it should be developed.



### Merced County

A deposit of manganese ore lies in the southwestern corner of Merced County, in the Coast Ranges and near the manganese deposits in San Benito County. It is a typical Franciscan deposit. No ore has been produced from it, and no other manganese deposits are known to occur in the county.

### Mono County

Manganese deposits are known to occur at six places in Mono County. They are situated in two areas, one about 10 miles northwest of Mono Lake and the other 20 miles to the north, near Sweetwater. No production prior to 1942 is reported, but one mine, the Taylor, is now producing manganese from a deposit that consists of a brecciated fissure zone in Tertiary volcanics, in which the interstices are filled with manganese oxide, much of it hard and botryoidal like psilomelane. Most of the other deposits are similar to this one, but in them the country rock is less brecciated and the ore is confined to small veinlets. One deposit, the Penrose, which lies in a valley bottom in an area of volcanic rocks, is said to consist of limonite and wad.

### Monterey County

Monterey County contains three manganese deposits, two in the southwestern part of the county and the third near the southeastern border, close to Stone Canyon. The deposits are of the Franciscan type. None of them seems particularly promising, and none has produced any ore.

### Napa County

Napa County is represented by 14 deposits, all in the northern half of the county. They are of two types: some are typical Franciscan deposits in chert interbedded with other sedimentary rocks; others are fairly large bodies of manganiiferous iron ore in chert that is enclosed in serpentine. The deposits of the first type contain on the average about 20 percent manganese, those of the second type less than 10 percent. The county produced 300 tons of oxide ore in 1918.

### Nevada County

Some 15 manganese deposits are known to occur in Nevada County. These lie in two main areas: in the southwestern corner of the county along Wolf Creek, north of Auburn; and fifteen miles to the northeast along Bear River, north of Colfax. The first-mentioned area contains nine deposits distributed in a northward-trending belt five miles long. The manganese ore occurs in chert in a zone of phyllite. The primary ore is rhodonite, but in the Manga-Chrome deposit, the most promising of this group, high-grade oxide extends to a depth of at least 30 feet. In the Bear River area north of Colfax, manganese ore occurs in well recrystallized chert in a zone of sericite schist. The primary ore consists of disseminated bodies of rhodonite, having a manganese content of about 20 percent. Some oxide ore was produced here from the Ryan deposit. A deposit near North Bloomfield—the Paine Brothers—con-

sists of low-grade manganese ferruginous chert having a manganese content of about 10 percent and a somewhat higher content of iron.

The production for the county during the first World War was 185 tons. The only mine that is known to be producing at present is the Manga-Chrome mine.

#### Placer County

Placer County is represented by 7 deposits, located in the central part of the county. All but one of these consist of segregations of manganese oxide or rhodonite in quartzite that is presumably recrystallized chert. The one exception is on the Lloyd property. Fragments of slightly brecciated, recrystallized chert cemented with manganese oxide are here scattered over the surface of the soil near an irrigation ditch, and they presumably come from an orebody below. One deposit, the Cape Horn, is reported to consist of a network of manganese oxide seams in alternating beds of quartzite, and schist, such as might be formed by metamorphism of thin-bedded chert and shale.

The production from the county has been 100 tons, divided between two mines, the Gold Hill and the Randel. The Gold Hill is reported to have produced some ore during the present war.

#### Plumas County

Manganese has been reported from 15 localities in Plumas County. Most of them lie in a northwestward-trending belt of metamorphosed shales, tuffs, and volcanic rocks near Crescent Mills, in the center of the county. One deposit, the West and Shaw, lies about 10 miles east of Taylorsville, and two, the Penrose Lode and the Sierra Manganese or Diadem Lode, are in the southwestern part of the county, near Meadow Valley. The production from the county to the end of 1941 has been 4,000 tons. The ore has come mainly from two mines, the Braitto or Iron Dyke, and the Crystal Lake, both located within a small area near Crescent Mills. These two mines are now producing again.

The deposits near Crescent Mills lie generally parallel to the strike of the beds, and some of them seem to be related to a series of strike fissures, along which silica and perhaps manganese have been introduced into the rocks, forming irregular, elongate bodies of bright red and yellow jasper. The manganese ore is associated with the jasper, and in places it is found in veins up to 6 feet in width. At the Braitto mine the primary ore is largely braunite; at other mines it is a manganese chert, and at still others it is probably rhodonite. It is cut by quartz veins, which here and there contain the manganese epidote, piemontite. In places the piemontite is so abundant, and has been oxidized to such an extent, as to make a low-grade oxide ore.

#### Riverside County

There are 12 deposits, or groups of deposits, of manganese ore in Riverside County, clustered in four main areas. One area is in the western part of the county, near Elsinore; a second is near Mecca, in the south-central part of the county; a third is the Ironwood district, at the north end of the McCoy Mountains, about 25 miles northwest of Blythe; and the fourth is in the Little Maria Mountains south of Midland, 10 miles east of the Ironwood district. The county's total production has been 6,750 tons.

The Elsinore area contains two known deposits, the Beal-McClellan, Newport, or Black Eagle and the Elsinore. These deposits consist for the most part of partly oxidized rhodonite but contain some bementite and neotocite. They are in slightly recrystallized chert, interbedded with supposedly Triassic metasediments. The depth of oxidation is variable; in some places there is primary ore within 2 or 3 feet of the surface, elsewhere the ore is oxidized to a depth of as much as 20 feet.

The Ironwood district, sometimes called the McCoy-Ironwood region, has produced most of the ore that has come from Riverside County. About 5,000 tons has been produced by this district, from the Arlington, Black Jack, Social, Melville, Bray, etc. mines. The ore in the Ironwood district is found in brecciated zones along more or less parallel fissures in volcanic rocks. Its average manganese content is 20 to 25 percent. The mineralized zones can be traced for nearly a mile, but none of the individual ore shoots is more than 400 feet in length. Three of them are said to have been mined to a depth of about 100 feet, but the others have been worked only to depths of 50 feet or less. The width of the shoots is variable but usually less than 5 feet. The ore consists predominantly of hard manganese oxide, which resembles psilomelane and manganite, though some soft ore similar to pyrolusite also occurs. The abundance of hard manganese oxide should, it would seem, have facilitated the concentration of the ore, yet the dumps at the mines contain some 3,000 tons of material that has a manganese content only a few percent below the general average for the ore mined. The McCoy-Ironwood region still contains considerable ore, and production is actively proceeding at the present time.

The deposits in the Langdon group of claims, which lie 10 miles east of the Ironwood district, consist of segregations and veins of manganese oxide in limestone interbedded with quartzite. Several of these deposits have been worked, all of them in the same stratigraphic zone and similar in character. The region produced 1,500 tons of ore during the last war, but it has not produced any since the present war began. The manganese content of the ore as it would have to be mined is relatively low, but the grade could be increased by sorting and concentration. Two smaller deposits of the same type, located five miles north of the Langdon group, are the Paddy Faulkner and the Giant Chief.

No information is available regarding the deposits near Mecca. The Mountaineer mine, in the northeastern corner of the county, is a gold and copper mine which contains some manganese oxide along a fissure in limestone. Two deposits in the Palen Mountains (Doran and Palen Mts.) are said to be relatively inaccessible.

#### San Benito County

Seven deposits are known to occur in San Benito County. They are all typical Franciscan orebodies in chert. Four are scattered along the northeastern border of the county; two lie on either side of Panoche Pass, near the center of the county; and one occurs in the San Andreas fault zone east of Bitterwater, in the southern part of the county. The deposits are relatively small. The total production of the county has been 246 tons, which came from the Hawkins and Hannagan mines. The Hawkins deposit contains mangiferous chert and bementite. It has been hydrothermally altered and is associated with glaucophane schist.

The Hendricks mine is one of the most promising deposits in the county, but its ore is likely to pass into carbonate a short distance below the surface. The McCreary Ranch is the only property being developed at present.

#### San Bernardino County

About 20 deposits or groups of deposits are known to occur in San Bernardino County. They are located mainly in five areas, namely: (1) the south end of the Owls Head Mountains, near the north border of the county and south of Death Valley; (2), the Avawatz and Silver Lake region, about 25 miles south of the Owls Head Mountains; (3) the general vicinity of Ludlow and Newberry, 25 to 50 miles east of Barstow; (4) the Whipple Mountains west of Lake Havasu, north of Parker, in the southeastern part of the county; and (5) one deposit about 10 miles north of Needles.

Most of the deposits consist of manganese oxide in brecciated zones along fissures. Some of these grade downward into calcite impregnated with manganese oxide—the so-called black calcite type of deposit. An example is the Stewart mine, which occurs in fanglomerate. One deposit, the Black Stone, lies along the fracture zone between granite and limestone. It contains relatively little ore. Another, the Gallagher or Black Mountain deposit, consists of lenses of manganese oxide, up to 3 feet thick, in granite. This deposit has an average manganese content of about 35 percent but is believed to contain only a small amount of ore. The fissure deposits in the Owls Head Mountains, the New Deal and the Emma or Black Magic, occur mainly in fanglomerate, but some are in granite.

The deposits between Newberry and Ludlow are fissure deposits in volcanic rocks. The Lee Yim or Garringer and Big Reef deposits possess brecciated zones as much as 10 feet wide containing rock fragments in a matrix of manganese oxide. The ore has a grade of 20 to 30 percent. In the Lee Yim deposit the manganese ore is associated with and grades downward into hematite. In both deposits the fissures have distinct footwalls, which in the Big Reef deposit has a remarkably smooth, polished, jasperoid surface. The Logan mine is in massive volcanic rock. The manganese ore, instead of forming a matrix for a breccia as in the above-mentioned deposits, occurs as distinct veinlets a few inches to one or two feet thick occupying parallel fissures over a width of 30 to 40 feet. The centers of these veinlets are commonly filled with white calcite, which is later in origin than the manganese oxide.

Bedded deposits of two types occur in the county. One is represented by the Owls Spring deposit, which consists of wadlike material having an average manganese content of about 5 percent, and by the very similar War Baby deposit of Inyo County, about 15 miles to the north. These deposits contain some tens of thousands of tons of ore, but relatively little of it is believed to have an average manganese content of more than 10 percent. A second type is exemplified by the Orchard deposit, a fanglomerate bed 40 feet thick and 1,000 feet long impregnated with manganese oxide. The average manganese content of this deposit is estimated to be less than 10 percent. The grade is different on the two sides of some fissures, which suggests that the ore

has been introduced, in part at least, by solutions. This deposit is therefore somewhat similar in origin to the fissure deposits that are so common in the general desert region.

Two deposits west of Lake Havasu in the Whipple Mountains, the Monument Peak and Moulton, consist of lenticular bodies of high-grade manganese oxide associated with hematite and jasper in a tuffaceous limestone, which is enclosed in Tertiary sandstone and volcanic breccia. It is uncertain whether the manganese has formed by replacement of the limestone or whether it is an original bedded deposit.

The production from San Bernardino County has been about 1,600 tons. Most of this has come from the New Deal and the Emma or Black Magic mines in the Owls Hole district. These mines are actively producing ore at the present time. Other deposits in the county which have been active during the present war are the Logan, Big Reef, Lee Yim, Monument King, Moulton, and Stewart.

#### San Diego County

San Diego County has nine recorded deposits of manganese. These are widely distributed: two are near Fallbrook in the northwest part of the county; one is east of the mountains 8 miles east of Julian; one is near the crest of the range that lies 6 miles south of the Cuyamaca Reservoir; four are near Jacumba, in the southeast corner of the county; and one is near Dulzura, in the southwestern part of the county near the Mexican border. None of these deposits has produced ore, and none of them has been worked recently.

The manganese ore occurs in many different ways, and all is of low grade. The two deposits in the northwestern part of the county, the Clark and the Machado, show manganese stains in aplite dikes. Another deposit, the Del Monte, consists of low-grade oxide in a shear zone in granitic rock. The Ruby deposit consists of rhodonite and spessartite in quartzite in mica schist, being apparently similar to the Sierra Nevada deposits. The Jacumba deposit consists of manganese-stained silicified zones in granite. The Sunrise deposit is a manganese-bearing vein in crystalline rocks. The Engineers Springs deposit is composed of iron-stained jasperoid in a sheeted rhyolite and contains little or no manganese.

#### San Joaquin County

The largest manganese mine in California, the Ladd mine, is in San Joaquin County. This mine was first operated in 1867, and was mined almost continuously until nearly 1900, the ore being used mainly in batteries. The mine was reopened during the first World War, and some 10,000 tons of ore, containing about 44 percent manganese and 12 percent silica, was mined at that time. The mine has not been operated since. The total production as given by different people ranges from 30,000 to 50,000 tons, but the size of the dump and the extent of the underground workings are more commensurate with the smaller figure than with the larger. The mine was worked on three levels about 75 feet apart, and the ore was mined mainly from one bed, which lies in white chert. This bed is 800 feet in length and 35 feet in maximum thickness. The part that was mined was from 1 foot to 16 feet thick.

It consisted of high-grade oxide ore, which contained between 40 and 45 percent manganese and was generally richest near the base of the bed. The part that was not mined consists of stockwork oxide ore containing 15 to 20 percent manganese. It is estimated that there are 170,000 tons of such ore, averaging 18 percent manganese, the cut-off being placed at 10 percent. The maximum depth of oxidation is about 250 feet. Some 10,000 tons of carbonate and bementite ore containing about 20 percent manganese is inferred to be present below the zone of oxidation.

Besides the Ladd mine, two other mines in San Joaquin County have produced ore: the Fabian mine, about half a mile northwest of the Ladd mine, and the Cummings, Section 13, or Lone Tree mine, about 3 miles south of the Ladd mine. The Fabian mine was for a while operated independently, but in 1917 it was taken up by the operators of the Ladd mine, and its production has since been combined with that of the Ladd mine proper. The mine may have produced as much as 2,000 tons, but its workings are now flooded, and no reliable estimate can be made from the size of the stopes. The Cummings or Lone Tree mine produced more than 2,000 tons during the first World War, but it seems to be largely depleted of high-grade ore. It was prospected considerably in 1942, but little ore has been produced thus far. The ore, which is found in at least two beds, is similar to that in the Ladd mine, except that there is little stockwork ore.

Four other manganese deposits have been worked in San Joaquin County but have produced no ore.

The deposits of San Joaquin County have been examined in detail by the Geological Survey, and a report on them by P. D. Trask and W. G. Pierce is in preparation.

#### San Luis Obispo County

San Luis Obispo County has produced about 5,000 tons of manganese. The past production has come from nine mines, of which the Welch and the Stanench have yielded the most. Two mines are now producing ore—the Johe and the Thompson. The ore is found at intervals in a belt of Franciscan rocks in the western part of the county throughout a distance of more than 60 miles. Some 29 deposits are known. Most of them are typical of the orebodies in Franciscan chert, though the ore in the vicinity of the Stanench mine has been hydrothermally altered and contains hausmannite. In several deposits, such as the Blue Bird, the Mayfield and the Vollmer or Quintano, the ore is associated with greenstone. In one deposit on the Hearst Ranch the ore consists of nodules of oxide in serpentine. The nodules seem to be a product of surface concentration due to weathering. The largest are about 5 feet in diameter. The average manganese content of the nodules is more than 35 percent, but the tonnage in sight is small. Another deposit on the Hearst Ranch consists of large boulders of calcite, about 5 feet in maximum diameter, containing disseminated manganese oxide. The manganese content of these boulders is estimated to be about 30 percent. Another type of deposit found in San Luis Obispo County consists largely of manganese opal or neotocite, oxidized in places to a moderately high degree. The Johe Ranch deposit is the best example of this type.

The Staneuch mine should not, perhaps, be considered as a potential source of ore, for it is part of an estate that is now subject to prohibitory provisions against mining. The mine produced considerable manganese during the last war, and it probably still contains high-grade ore; but the workings are now inaccessible, so that the amount of ore still available cannot be ascertained. The Welch mine, formerly the best producer in the county, is also caved, so that no reliable estimate of its reserves can be made, but it also probably still contains some ore.

#### **Santa Barbara County**

Only three small manganese deposits are known to occur in Santa Barbara County, all of them in or near a belt of Franciscan rocks in the central part of the county, some 10 miles northeast of Santa Ynez. None of them has produced any manganese. One of the deposits consists of a few blocks of mangiferous chert, another shows manganese stains in chert or jasper in altered Franciscan basalt, and the third consists of blocks of low-grade manganese ore in chert resting upon soil in a region of well-stratified boulder beds, 300 yards southwest of an outcrop of Franciscan rocks.

#### **Santa Clara County**

Nearly 50 deposits of manganese are known in Santa Clara County. Most of them are in the northeast corner of the county near the headwaters of San Antonio Creek, a few deposits lie a short distance northeast of San Jose, and a few are scattered. All are in the Franciscan formation and are similar to other Franciscan manganese deposits. The primary minerals are rhodochrosite and bementite, but as the depth of oxidation is about 100 feet and none of the orebodies is more than 200 feet in length, most of the deposits can be expected to be largely oxide. One, the Jones or Black Wonder group, passes into high-grade carbonate at a depth of 75 to 100 feet. The total production of the county to the end of 1941 was 3,100 tons and came from 19 properties. The mines that have produced more than 150 tons are the Pennsylvania, the Aitken-Wolfe, the Winegar, the Pine Ridge, the Miller, the San Jose, the Murmac, the Jones or Black Wonder, and the Matt Keller or Barker.

The construction of the plant of the General Dry Battery Company at Patterson has stimulated production in Santa Clara County, and eleven mines were producing on November 15, 1942. Ore from these mines contained from 20 to 50 percent of manganese. The most active mines in 1942 were the Jones, the Keller, the Pine Ridge, and the Winegar.

A detailed report by P. D. Trask and F. S. Simons on the deposits in the northeastern part of the county is in preparation.

#### **Shasta County**

Eight manganese deposits have been reported from Shasta County. One of these, at the Shasta Copper Company mine, is near Kennett, in the middle of the county, and another is nearby; one is in the northern part of the county, southwest of Big Bend; the others are in the southwestern tip of the county. The total manganese production for the county up to the end of 1941 consisted of 1,000 tons of ore, mined by



the Shasta Copper Company in 1918. This ore is said to have contained 27 percent manganese, and was used for making silico-manganese. The Nigger Hill deposit produced a small amount of manganese in 1942.

The ore is of four types: (A) replaced siliceous porphyry adjacent to a mass of red jasper (Shasta Copper Company deposit); (B) manganese oxide in thin-bedded metamorphosed chert, in which the primary mineral is probably rhodonite (Victor and Nigger Hill deposits); (C) rhodonite segregations in chert interbedded with greenstone (Goat Camp deposit); and (D) manganiferous chert associated with greenstone (Nicol deposit). All the orebodies are small except those at the Shasta Copper Company and Nigger Hill mines. The Nigger Hill deposit contains a relatively large amount of low-grade ore, with less than 5 percent manganese.

#### Siskiyou County

Manganese deposits are known to occur at about 30 places in Siskiyou County, all in the western part of the county. They are mainly in three areas: (1) near Happy Camp and Seiad Valley, near the Klamath River; (2) between Fort Jones and the settlement of Oro Fino, 20 miles southwest of Yreka; and (3) near Sawyers Bar, in the southwestern part of the county. The reported production prior to 1942 was only 50 tons. Three mines are said to have shipped ore in 1942—the Fort Jones, the Chaparral Hill, and the Mayland.

The primary ore in Siskiyou County is mainly rhodonite, and all of it is found either in chert or in fine-grained quartzite that appears to be metamorphosed chert. The depth of oxidation is in general only a few feet. The prevailing type, exemplified in the Mayland deposits near Sawyers Bar, consists of alternating thin layers of quartzite and of quartzite and rhodonite. Most of these deposits contain but a small amount of ore, with a manganese content between 10 and 25 percent. The Mayland deposit is estimated to contain a relatively large quantity of rather low-grade rhodonite ore.

Some of the deposits contain massive rhodonite, but these deposits are lenticular and do not seem to have much ore. The largest deposit of this type that was seen is the Rhodonite deposit, 10 miles north of Happy Camp.

A small deposit of banded quartzite and rhodochrosite (Oro Fino 2) extends along the ridge east of the settlement of Oro Fino. The deposit is lenticular and looks much like metamorphosed pods of manganese ore in chert. The ore is estimated to contain about 20 or 25 percent manganese, and it might be concentrated to a satisfactory shipping grade for rhodochrosite if sufficient tonnage could be found to warrant setting up a plant. One possible deposit of this type (Chaparral Hill) lies like a blanket over the surface of the ground, and presumably most of the manganese in it has been oxidized.

On Elk Creek, about 10 miles south of Happy Camp, a belt of manganiferous chert 300 feet in width crops out for a distance of at least 1,000 feet. The ore is of low grade, its manganese content being probably less than 5 percent, but there are several million tons of it.

Quartzite and chert stained with manganese oxides are found in several places, but such material is so low in grade as to be of little importance.



### Sonoma County

Eighteen deposits are reported from Sonoma County, all in the northern half of the county. Most of them lie along the eastern border; a few lie in a northwestward-trending belt in the center of the county; and one, the Aho mine, is near the ocean, 3 miles northeast of Fort Ross. The production from the county has been 1,500 tons. The Boyer and Aho mines are the principal producers. Some 50 tons in all has been produced from two other mines—the Dillon and Seefeldt and the Dreamland. The Aho mine produced some ore in the summer of 1942, but is now abandoned. The remaining ore is almost entirely carbonate, neotocite, and bementite. The other mines that produced during the first World War seem to have been largely exhausted.

The ore, all of which comes from the Franciscan formation, is of three types: (1) bedded carbonate in chert, altered to oxide at the surface (Aho mine); (2) low-grade stockwork ore and manganiferous chert (most of the deposits); and (3) manganiferous chert associated with greenstone (Pine Flat, Sharp, and Warner).

### Stanislaus County

Stanislaus County is one of the largest producers of manganese in the State, its total production to the end of 1941 having been 17,690 tons. Eleven mines are now being worked, namely: the Buckeye, Tip Top, Liberty, Moran Bros., Grummett Knox, Hamilton, Gerber, Mezero, Section 23, Jake Smith, and Coast Manganese. About half the ore from those mines has gone to the General Dry Battery Company at Patterson, and the remainder has been shipped to the Metals Reserve Company stockpile at Sacramento.

The principal producer in Stanislaus County has been the Buckeye mine, which has yielded more than 10,000 tons of oxide ore and perhaps as much as 2,000 tons of high-grade carbonate ore, containing between 40 and 43 percent manganese. The mine is now actively producing oxide ore, and it still contains appreciable reserves, principally of carbonate and hausmannite ore.

The Liberty mine, situated 2 miles northeast of the Buckeye mine, produced more than 2,000 tons of high-grade oxide ore during the first World War and is now being operated again. The other mines in the county produced in the aggregate less than 1,000 tons prior to the present war, but the advent of the General Dry Battery Company's plant at Patterson caused the reopening of several old mines and the opening of a few new ones, including the Tip Top and the Hamilton or Mitchell.

Some details concerning the deposits in the vicinity of the Buckeye mine and deposits in the southwestern part of the county are given on preliminary maps recently issued by the Federal Geological Survey.

### Tehama County

Manganese is reported from seven localities in Tehama County. Two of these are in the northwestern part of the county, a short distance east of North Yolla Bolly Mountain; the others are in the southwestern part, a few miles west of Paskenta. No ore has yet been produced from Tehama County, and the deposits that have been visited are

small and of low grade. One group of deposits, on the Tehama claims, located on the southeast slope of North Yolla Bolly Mountain, has not been examined but may be examined in 1943. A sample of ore from this locality, consisting of manganese oxide in quartzite, was estimated to contain between 10 and 15 percent manganese. By analogy with sections in the projection of the strike to the northwest, the deposit is inferred to be in the series of metamorphic rocks that is exposed east of South Fork Mountain, in Trinity County. If this inference is correct, the primary ore can be expected to contain rhodonite.

The other deposit near Yolla Bolly Mountain (Manganese King), consists of alternating layers of granular bementite and oxide in chalcodony. The deposits near Paskenta consist of low-grade oxide, mangani-ferous chert, and carbonate in chert lenses associated with serpentine and greenstone.

#### Trinity County

Trinity County contains a larger number of manganese deposits than any other county in California, 100 localities having been recorded. The county's total production has been about 2,100 tons. Only 138 tons was produced in 1918, from deposits at the White and Moody mines, near Alder Point in the southwestern part of the county; the rest was produced in 1942, mainly from the Blue Jay and Manganese Queen mines. The ore from the Blue Jay mine consists of high-grade oxide, hausmannite, and a little carbonate. It contains on the average 50 to 54 percent manganese. The ore from the Manganese Queen mine consists of a mixture of rhodonite, rhodochrosite, and a mineral that looks like bementite; but, as the average manganese content of the raw ore is 42 to 44 percent, which is too high for either rhodonite or for the amount of rhodochrosite present, the mineral that looks like bementite is probably something else, perhaps hausmannite or brannite. The ore was crushed to about 1 inch, and calcined before being delivered to the Metals Reserve Company stock pile in Sacramento. Early in November 1942, mining operations at this mine were stopped, presumably because the ore that was being encountered contained too high a proportion of rhodonite. The remaining 1942 production from Trinity County came from the Coldwater No. 1 and No. 2, Black Oak, Shell View and Rainy Day deposits.

In 1941 about 600 tons of carbonate and hydrous silicate ore was mined from the Hale Creek deposit, on the Mad River about 20 miles northwest of the Blue Jay deposit, but as no market for the ore could be found it was placed in a stock pile at the mine. This ore contains about 35 to 40 percent manganese and is high in silica.

The manganese deposits of Trinity County are all, roughly speaking, in the southern half. They fall into three groups, namely: (1) in the southwestern part of the county, near Alder Point; (2) along the course of the Mad River; and (3) in the drainage basin of the Trinity River, mostly south of Hayfork. All of the deposits occur in chert. Those of the first two groups are in Franciscan rocks, while those in the Hayfork district are in older rocks, which are more or less metamorphosed.

The deposits in the Mad River and Alder Point districts are similar to others in the Franciscan formation. The country around Alder Point is characterized by landslides and by complicated structure, and its

orebodies, which are small, are broken by faults. The primary ore minerals in the Alder Point district are rhodochrosite and neotocite, but rhodonite and other hydrothermal silicates are present in the Shell View mine. In the upper Mad River region the primary ore is a mixture of carbonate, bementite, and hausmannite. At some places in the Blue Jay mine perhaps as much as half the rock consists of hausmannite. Inesite is found in the Hale Creek deposits, 20 miles northwest of the Blue Jay mine. About 10 miles east of the Blue Jay mine, in the continuation of the belt of Franciscan rocks in which the ore is found in the Mad River region, bedded deposits of carbonate and bementite and of mangiferous chert are found on the south side of Yolla Bolly Mountain on the divide between the Eel and Trinity rivers. These are known as the Yolla Bolly deposits (Emma, Bertha, and Dahrman).

The deposits in the Trinity River basin are of two types, found in two northwestward-trending belts of chert about 5 miles apart. One type is characterized by the presence of rhodonite and is associated with moderately basic plutonic intrusions. The other consists of thin-bedded mangiferous chert, which contains less than 10 percent manganese. This is at best a low-grade ore, but a relatively large tonnage of it is available. Both types, where associated with serpentine, may contain considerable iron. The rhodonite type is represented at the Manganese Queen, Spider, and Lucky Bill properties; the mangiferous chert type at the Snow Camp, the Carr, and the Two Sugar Pines; and the mangiferous iron deposits at the Dry Lake and Arrowhead.

#### Tulare County

Tulare County contains five known manganese deposits, which are widely scattered, four being in the west-central part of the county and one near the northern boundary. The county has not produced any manganese. The manganese ore occurs in several different ways. One deposit, that on the Gill Ranch property, consists, like others in the Sierra Nevada, of oxide and rhodonite in metamorphic rocks. Another, the Barbour deposit, is a quartz vein in granodiorite, 1.5 feet wide and containing a streak of soft manganese oxide about 4 inches wide. A third deposit, the Cole, consists of mangiferous iron oxide in jasper or chert interbedded with slate. Still another, the O'Kelly deposit consists of manganese stains on metamorphic rocks. The exact location and the character of one deposit, the Dry Creek, has not been ascertained.

#### Tuolumne County

Ten deposits are reported from Tuolumne County, all of them in the western part of the county, in the general vicinity of the Mother Lode. Production has been about 50 tons, all from the Hughes, and Wonder mines. The deposits are similar to those in Calaveras County, to the north. Most of them are in recrystallized chert of the Calaveras series. The ore in these consists of segregations of oxide, rhodonite, and spessartite, and has an average manganese content of 10 to 20 percent. Other deposits, which occur in chert of the Amador group, consist mainly of rhodonite, but one of them, in the Hughes mine, may also contain some rhodochrosite and bementite. The Jasper deposit is a banded quartzite stained with manganese oxide. Another deposit, the

Schoettgen, consists of manganese oxide lying as a superficial residue on limestone. The ore contains less than 10 percent manganese, and there is very little of it.

#### Yuba County

Two small manganese deposits are known to occur in Yuba County, both in the northeast corner of the county. Each consists of rhodonite ore in slightly recrystallized chert, which forms part of the metamorphic basement complex. The depth of oxidation is small.

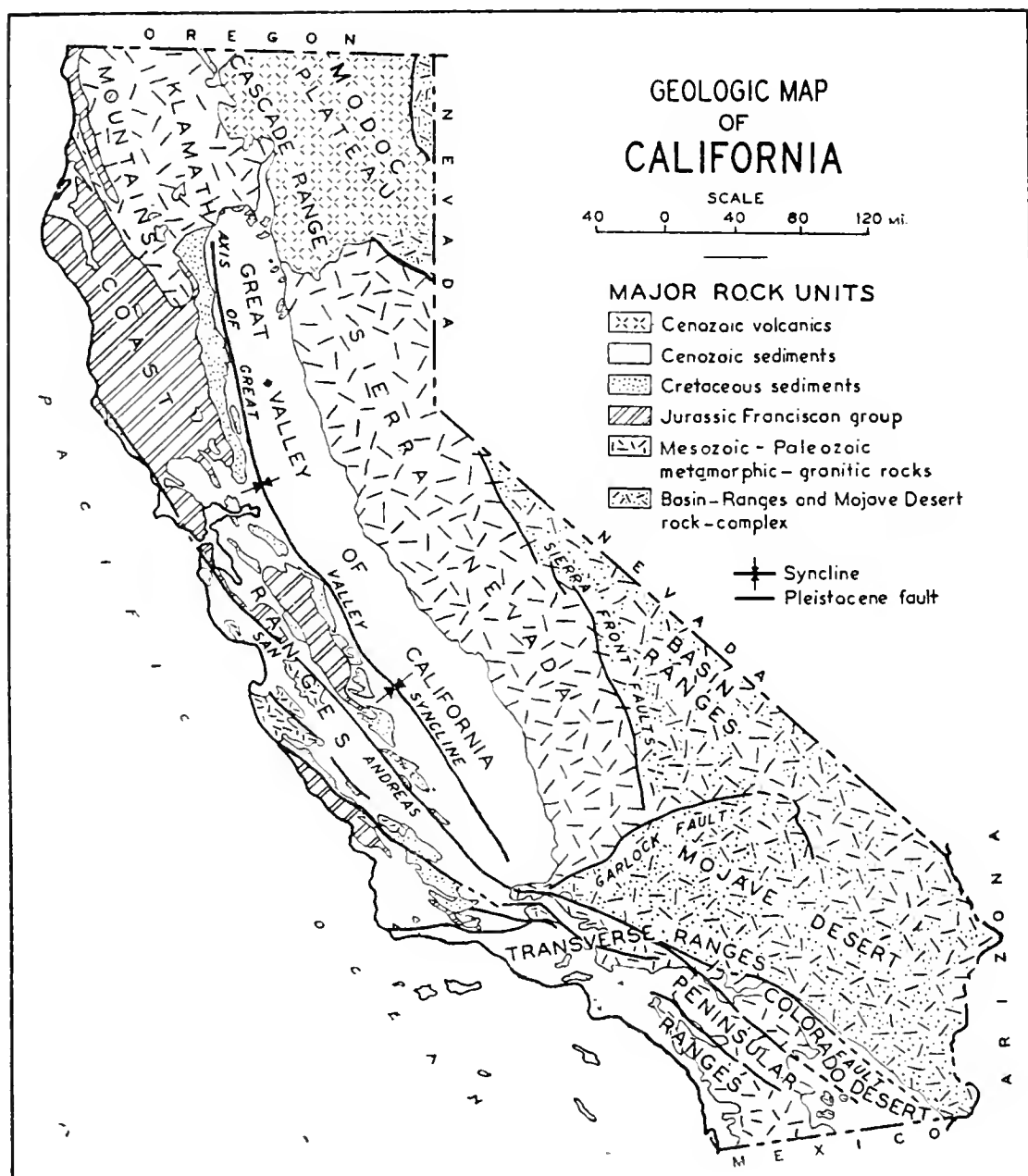


Fig. 1. General geologic map of California showing relationships of major rock units to the geomorphic provinces, which consist of the following: (1) Great Valley of California; (2) Sierra Nevada; (3) Cascade Range; (4) Modoc Plateau; (5) Klamath Mountains; (6) Coast Ranges; (7) Transverse Ranges; (8) Peninsular Ranges; (9) Colorado Desert; (10) Mojave Desert; and (11) Basin-Ranges. Prepared by Olaf P. Jenkins.

## TABULATED DATA ON MANGANESE PROPERTIES OF CALIFORNIA

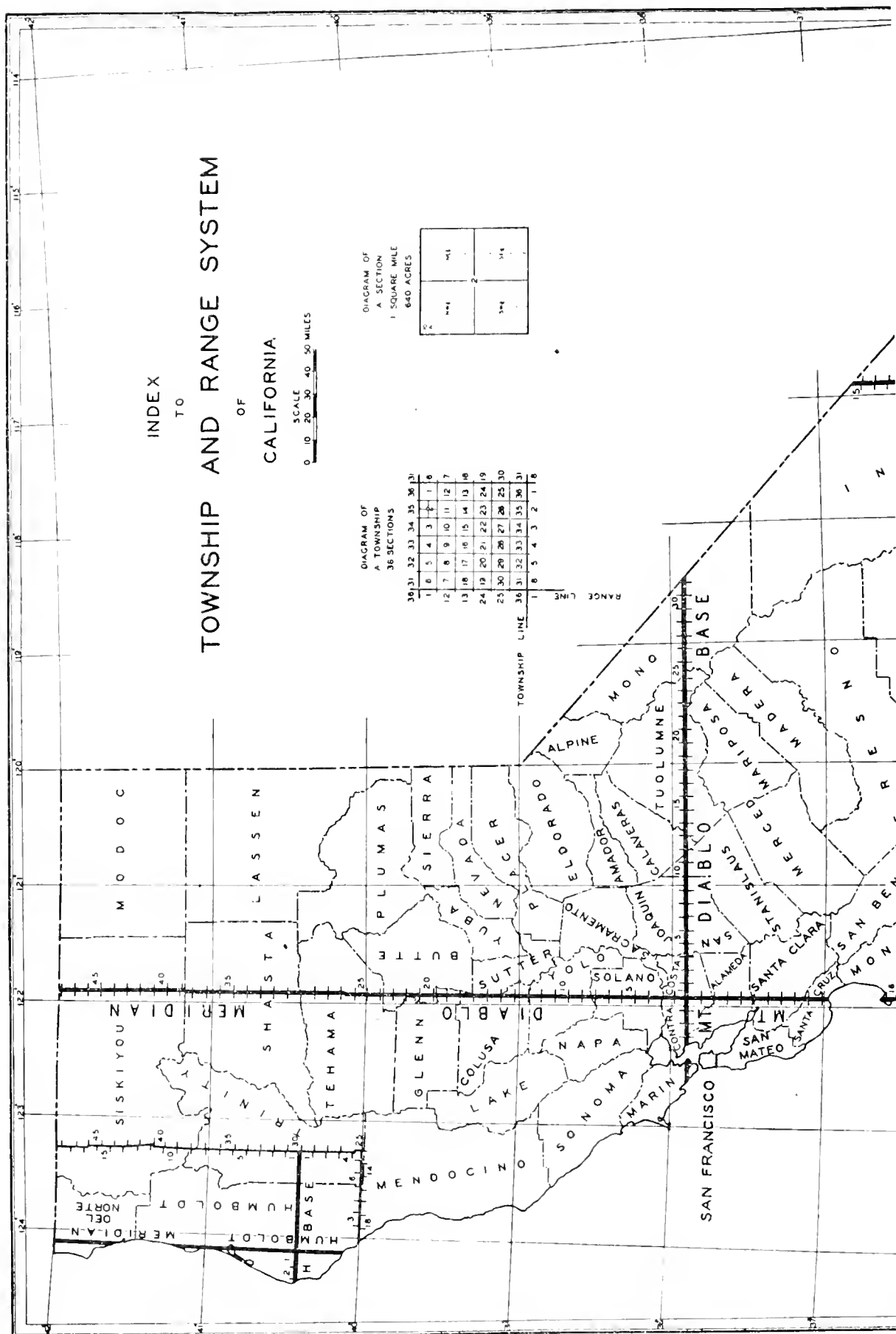
In the following tables an attempt is made to list all of the known manganese deposits in California. The source of the data is from recent field investigations of the Geological Survey, United States Department of the Interior; unpublished reports of the California State Council for Defense, prepared in 1917 and 1918 in cooperation with the Geological Survey and Bureau of Mines, United States Department of the Interior; published reports of the California State Division of Mines, particularly Bulletin 76 (1918), *Manganese and Chromium in California*, by Walter W. Bradley, E. Huguenin, C. A. Logan, W. B. Tucker, and Clarence A. Waring; and from miscellaneous published and unpublished reports, including the results of field investigations by the Bureau of Mines, United States Department of the Interior, and by the California State Division of Mines. Final reorganization of this list was done by Elisabeth L. Egenhoff, California State Division of Mines.

In compiling the tables use was made of a tabulated list of manganese deposits of California compiled in 1941 by Robert S. Kroger as part of a graduate thesis in the Department of Mining, Stanford University. This work was done under the supervision of Professor Charles A. Dobbel as a cooperative project with the Geologic Branch of the California State Division of Mines.

The tables are designed to accompany *Economic Mineral Map of California, No. 5—Manganese*, prepared under the direction of Olaf P. Jenkins, which is folded in the pocket of this bulletin.

*California counties in which manganese deposits occur*

County	Number of Deposits	County	Number of Deposits
1. Alameda.....	31	23. Monterey.....	3
2. Amador.....	15	24. Napa.....	14
3. Butte.....	10	25. Nevada.....	15
4. Calaveras.....	17	26. Placer.....	7
5. Colusa.....	3	27. Plumas.....	15
6. Contra Costa.....	1	28. Riverside.....	12
7. Del Norte.....	2	29. San Benito.....	7
8. El Dorado.....	6	30. San Bernardino.....	21
9. Fresno.....	8	31. San Diego.....	9
10. Glenn.....	10	32. San Joaquin.....	7
11. Humboldt.....	15	33. San Luis Obispo.....	29
12. Imperial.....	11	34. Santa Barbara.....	3
13. Inyo.....	11	35. Santa Clara.....	45
14. Kern.....	10	36. Shasta.....	8
15. Lake.....	33	37. Siskiyou.....	31
16. Los Angeles.....	4	38. Sonoma.....	18
17. Madera.....	6	39. Stanislaus.....	28
18. Marin.....	6	40. Tehama.....	7
19. Mariposa.....	7	41. Trinity.....	105
20. Mendocino.....	61	42. Tulare.....	5
21. Merced.....	1	43. Tuolumne.....	10
22. Mono.....	6	44. Yuba.....	2
		Total.....	675



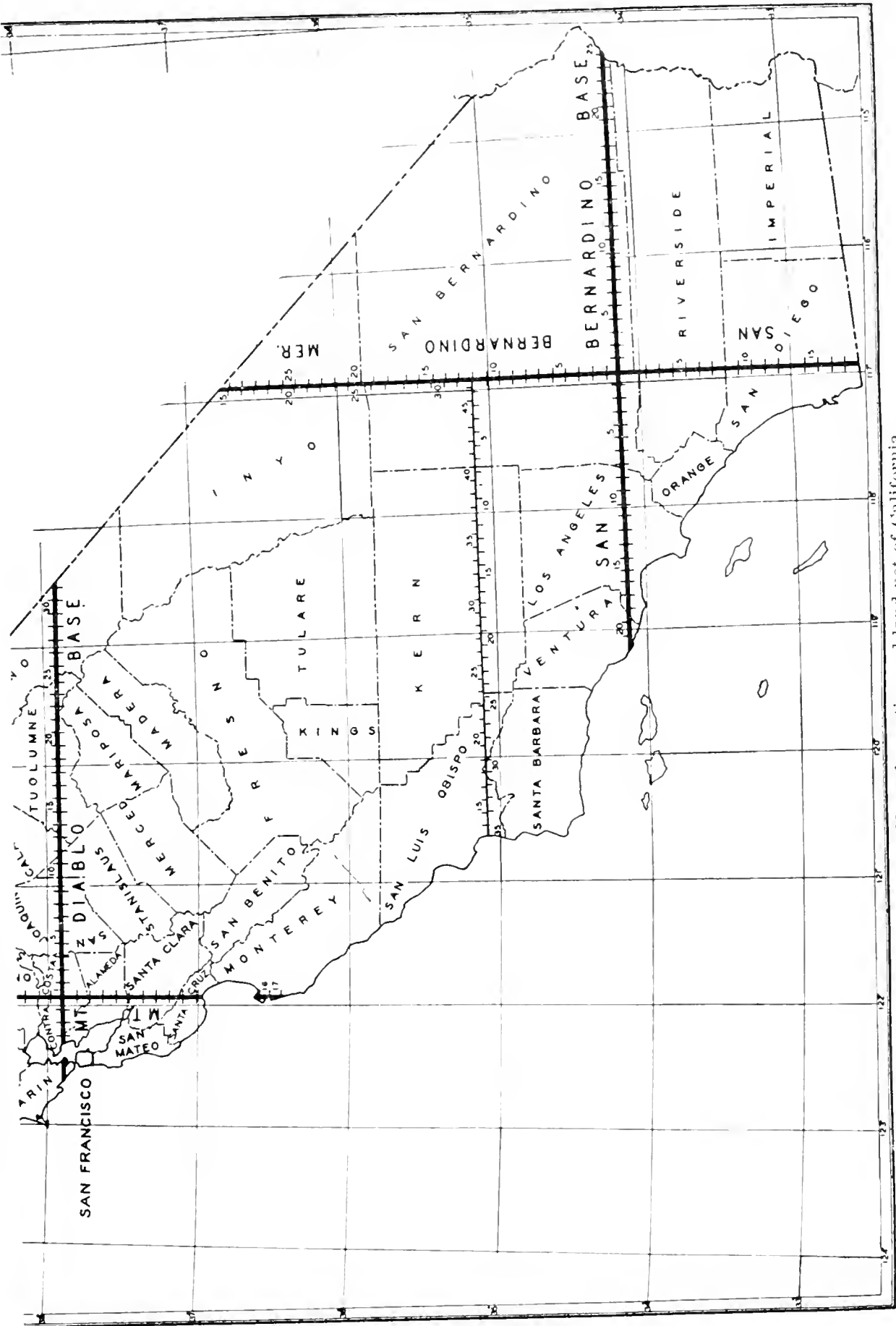


Fig. 2. Map of counties and land net of California.

### Explanation of the Tables

The following tables are arranged alphabetically by counties. Of the 58 counties of California, 44 are known to contain deposits of manganese.

*Column 1 (No.)* The deposits of each county have been arranged alphabetically by name, and numbered. The numbers on the accompanying *Economic Mineral Map of California No. 5—Manganese*, correspond with the numbers in this column; however, where the location of a deposit is indefinite, or where many locations are crowded together, numbers are omitted from the map, and are carried only in the list.

*Column 2 (Name of Claim).* Names appearing first in this column are the ones in current use; other names by which the deposit is known are given in parentheses. Listing is alphabetical under each county.

*Column 3 (Name of Owner).* The name of the owner, lessee, or operator is recorded in this column, when known.

*Column 4 (Location: Sec., T., R., B. & M.)* Whenever possible, location is given in terms of section, township, and range.

*Column 5 (Class by Prod.)* Letters in this column indicate approximate production, including that for 1942 when it is known. Letters have the following signification:

A—Production 1,000 tons or more.

B—Production 150 to 999 tons.

C—Production 1 to 149 tons.

D—No production.

*Column 6 (Remarks and References).* This column contains:

- A. Remarks about the nature of the ore. Minerals listed here are generally those in the primary ore. Most of the deposits contain oxides at the surface of the ground.
- B. Source of information concerning the deposit. The figures (1), (2), and (3) supply the following information:
  - (1) The deposit was examined by the Geological Survey, United States Department of the Interior, in 1940-1942.
  - (2) Information was derived from unpublished reports of California State Council for Defense, prepared in 1917 and 1918 in cooperation with the Federal Geological Survey and Bureau of Mines under the direction of G. D. Louderback, by N. L. Taliaferro, F. S. Hudson, E. F. Davis, R. R. Morse, A. O. Woodford, T. H. Crook, and other geologists.
  - (3) Information was from miscellaneous sources, including cards in files of the Geological Survey, letters from or conversations with owners of properties, access-road applications, and other sources.
- C. Bibliographic citations. Most of the citations in this column are to State Mineralogist's reports and bulletins of the California State Division of Mines (Cal. Div. Mines R17:28; Cal. Div. Mines B76:28); numbers following the colon refer to the page on which the reference occurs. Citations to *Mineral Resources of the United States* and *Mineral Industry* are given as follows: Min. Ind. v14:435 (Mineral Industry, volume 14, page 435); Min. Res. U. S. 1882:424 (Mineral Resources of the United States for 1882, page 424). Citations to other publications are by name of author and date; for instance, Harder, E. C. (10) 160 refers to page 160 of a report by E. C. Harder, published in 1910. The reports to which such reference is made are listed in the bibliography.



## ALAMEDA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
	Bailey: see Nelson lease							
1	Bartlett	H.H. Pitcher	6	4S	4E	MD	B	Franciscoan type Cal Div Mines R13:506; R12:329; R11:121; B38: 335
2	Beraudiere	John M. Beraudiere	NW14	4S	3E	MD	C	Franciscoan type (2) Cal Div Mines R25:436; R17:24; B76:25
3	Black Jack	H.T. Overacker (E.C. Rumphreys, former lessee)	NE14	4S	3E	MD	B	Franciscoan type (2) Cal Div Mines R25:436; R17:25; R13:506; B76:25; B38:335 Harder, E.C. (09) 271; (10) 160
4	Buckhorn	Chas. J. Janson	31	4S	4E	MD	D	Franciscoan type (2) Cal Div Mines R25:436; R17:25; B76:25
5	Camp 9 (Merchant, Cummings)	Crocker Estate	9	4S	3E	MD	A	Franciscoan type (2) Cal Div Mines R25:436; R17:25; R13:506; R12: 329; B76:26; B38:335 Harder, E.C. (10) 160 Min Ind v14:435
6	Chancy lease (Winship, Donovan, Doak)	Frank J. Rodriguez	NE12	4S	3E	MD	C	Franciscoan type (1) Cal Div Mines R25:437; R17:28; B76:28 Dolbear, S.H. (15) 174; (15a) 259

## ALAMEDA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
7	Corral Hollow	O.W. Mendenhall (J.W. Merchant, former lessee)	22	4S	3E	MD	B	Franciscan type Cal Div Mines R13:506; B38:367
8	Crosby	Wm. Crosby Estate	SW30	4S	3E	MD	D	Franciscan type (2) Cal Div Mines R25:436; R17:26; B76:26
9	Cummings: see Camp 9  Dewhirst	Mrs. Amanda Dew- hirst (McDonald and Clark, for- mer lessees)	SW22	4S	3E	MD	C	Franciscan type (2) Cal Div Mines R25:436; R17:26; B76:26
10	Doak: see Chaney lease  Donovan: see Chaney lease  Dyer	Dyer Estate	17	2S	3E	MD	D	Replaced limestone peb- bles in soil (1)
11	Elliot and Searles: see Man Ridge  Ellis Ranch  Estacia: see Newman	Edward T. Ellis	28	3S	3E	MD	D	Franciscan type Cal Div Mines R25:436; R17:26; B76:26

## ALAMEDA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
12	Freitas	Freitas	8	4S	3E	MD	D	Francisoan type (2) Cal Div Mines R25:436; R17:27; R13:506; R12: 329; B76:27; B38:335
13	Friggel	R. Friggel	NW22	4S	3E	MD	D	Francisoan type (2) Cal Div Mines R25:436; R17:27; B76:27
14	Gallagher	Dan Gallagher	13 19	4S 4S	3E 4E	MD	C	Francisoan type (1)
15	Graves (Grey Fox)	J.B. Graves et al	7, 18 12	5S 5S	4E 3E	MD	B	Francisoan type
	Grey Fox: see Graves							
	Haecke: see Man Ridge							
16	Hearst	J.W. Hearst	30	4S	4E	MD	D	Francisoan type Cal Div Mines R13:506
17	Romestead						D	SE of Livermore Francisoan type Harder, E.C. (10) 160
18	Isler Mountain						D	SE of Livermore Francisoan type Harder, E.C. (10) 160

## ALAMEDA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
19	Jumbo	John M. Beraudiere	NE14	4S	3E	MD	D	Franciscoan type (2) Cal Div Mines B76:27
20	Kelly	Mrs. Kelly (Holbrook and McGuire, former lessees)	5	4S	3E	MD	D	Franciscoan type (2) Cal Div Mines R25:436; R17:27; B76:27
21	Livermore						D	Franciscoan type (3)
22	Man Ridge (Scott and Winegar, Elliott and Searles, Raeoke)	Phil Winegar Arthur Most	7	5S	4E	MD	B	Active Franciscoan type (1,2) Cal Div Mines R25:436, 437; R17:26,27,28; B76: 28
23	Mendenhall	O.W. Mendenhall	NE12	4S	3E	MD	C	Franciscoan type Cal Div Mines R13:506; R12:329
	Merchant: see Camp 9							
24	Mount Hamilton	Walton Van Winkle former lessee					D	Franciscoan type (3)
25	Nelson lease (Bailey, Newhall lease)	Holm Bros.	NW10	4S	3E	MD	B	Active Franciscoan type (1,2) Cal Div Mines R25:436; R17:27; B76:27
	Newhall lease: see Nelson lease							

## ALAMEDA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S.c.	T.	R.	B. & M.		
26	Newman (Estacia)  Pitcher, Taylor and: see Taylor and Pitcher	Mabel Newman (McDonald and Clark, former lessees)	22	4S	3E	MD	C	Franciscoan type (2) Cal Div Mines R25:436; R17:27; R13:506; R12: 329; B76:27; B38:335
27	Reay	W.R. Reay	36	3S	3E	MD	D	Franciscoan type Cal Div Mines R25:437; R17:27; B76:28
28	Root  Scott and Winegar: see Man Ridge Searles, Elliott and: see Man Ridge	J.W. Root	7 or 18	5S	4E	MD	B	Franciscoan type Cal Div Mines R25:437; R17:27; B76:28
29	Section 14	Lee Ogler (Phil Winegar, lessee)	14	5S	3E	MD	P	Active Franciscoan type (1)
30	Taylor and Pitcher	Taylor and Pit- cher	Appr 1	4S	3E	MD	B	Franciscoan type Cal Div Mines R13:506; R12:329
31	Winegar  Winegar, Scott and: see Man Ridge Winship: see Chaney lease	H.V. Winegar	4	5S	4E	MD	D	Franciscoan type (2) Cal Div Mines R25:437; R17:28; B76:28

## AMADOR COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sr.	T.	R.	B. & M.		
1	Alexander	Jack Alexander	29	7N	11E	MD	D	Rhodonite and ferruginous chert (1)
2	Big Gulch	C.W. Vose	NW 4	7N	12E	MD	D	Superficial deposits beneath lava (1)
3	Crocker-Preston: see Peyton Custer (Dooley)	R.J. Custer	28	6N	10E	MD	D	Rhodonite near greenstone (1)
4	Deaver Dooley: see Custer	Ed Hutchinson	31	8N	12E	MD	D	Oxide (derived from rhodonite?) (1)
5	Du Frene	Fred Du Frene	SW27	6N	10E	MD	D	Rhodonite near greenstone (1)
6	Eagle's Head	Harvey L. Helbing	N 4	7N	12E	MD	D	Superficial deposit beneath lava (1)
7	Everett	L. Everett	31?	7N	13E	MD	D	Rhodonite? Cal Div Mines R23:201; B76:30
8	Germolis (Rodonick) Hubberty: see Rubser and Hubberty	Paul Germolis	NW10	7N	11E	MD	D	Rhodochrosite in metamorphosed chert (1)

AMADOR COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
9	Jones	D.C. Stowe	32	7N	12E	MD	D	Oxide (derived from rhodonite?) (1)
10	Lubanko	Louis Lubanko	SE10	7N	11E	MD	C	Rhodochrosite (1)
11	Martell						C	(3)
12	Pereni (Peyton lease)	Ben Pereni	NW35	7N	12E	MD	C	Oxide derived from rhodonite (1) Cal Div Mines R23:201; B76:30
13	Peyton (Crocker-Preston)	Lee Peyton	SW35	7N	12E	MD	C	Oxide from rhodonite (1) Cal Div Mines R23:200; B76:29
	Peyton lease: see Pereni							
	Preston, Crocker-see Peyton							
	Rodonick: see Germolis							
14	Ruhser and Hubberty	F.W. Ruhser Adam C. Hubberty	Appr 29	7N	13E	MD	B	Cal Div Mines R23:201; B76:30
15	Stirnman	Mrs. Lydia E. Blakemore (Dr. J.T. Stacy, lessee)	SE24	7N	12E	MD	B	Active Oxide from rhodonite (1) Cal Div Mines R23:201

BUTTE COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
1	Bear Canyon	George W. Woolley	34	20N	7E	MD	B	Oxide derived from rhodonite (1) Cal Div Mines R26:408; R24:208; R15:224; B76: 30
2	Binet	James T. Binet	34 or 35	20N	7E	MD	D	Manganiferous chert (1)
3	Black Raven	Wm. Vance	27	20N	7E	MD	D	(3)
4	Josephson	W.C. Josephson	10	21N	4E	MD	D	Oxide (1)
5	Lashbough and Foley	Lashbough and Foley					C	Active (3)
6	Shamberger	C.F. Shamberger	NW35	20N	7E	MD	D	Manganiferous chert (1)
7	Smithwick and Noble	Smithwick and Noble					C	Active Near Butte Meadows (3)



## BUTTE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
8	Steep Hollow	Jackson Mullings	S21	20N	7E	MD	D	Manganiferous chert (2)
9	Sunny Park (Powell)	Frank Tade	SE35	20N	7E	MD	D	Oxide from rhodonite (1) Cal Div Mines R26:408; R24:208; R15:224; B76: 30
10	View Point	E.C. Binet	34 or 35	20N	7E	MD	D	Manganiferous chert Cal Div Mines R26:408; R24:208; R15:224; B76: 30

## CALAVERAS COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	B. & M.		
1	Airola	Mrs. Emma Airola (John T. Martin, lessee)	SW35	3N	13E	MD	D	Active (1) Rhodonite and spessartite
2	Big Little Bear (Calaveras Manganese)	Alvin Maxwell Elmer Walker Aurelio Albertoni	24	3N	11E	MD	D	Manganiferous chert (1)
	Calaveras Manganese: see Big Little Bear							
3	Callahan	George Callahan H.H. Donner	34	2N	11E	MD	D	Rhodonite (1)
4	Carley	George Carley	SE12	3N	13E	ML	D	Spessartite (1,2)
5	Cave City	Thomas Bros. (F.P. Bassler, lessee)	14	4N	13E	MD	D	Manganiferous iron oxide in schist (1)
6	Daniels (Dennis)	Mrs. Minnie M. Dennis	6	2N	11E	MD	D	Rhodonite (1)
	Dennis: see Daniels							
7	Fortner Ranch	Dorothy Ludwig	4	4N	12E	MD	D	Spessartite (1) Cal Div Mines R21:163; B76:31 Harder, E.C. (10) 164 Turner, H.W. (94)

## CALAVERAS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
8	Gorham	Harry Beckwith	SE18	1N	13E	NL	D	Phodonite (2)
9	Harrington (Manganese)	F.M. Harrington (L.A. St. John, former lessee)		3N	14E	MD	D	Spessartite and rhodonite (2)
10	Hauseit	John Hauseit		3N	13E	MD	D	Spessartite and rhodonite (2)
11	Joses Ranch	L.B. Joses	N 5	4N	13E	MD	D	Manganiferous chert (1)
12	Kellogg (Vanella, Manilla)	W.M. Kellogg (Wallace A. Russell, lessee)	4	2N	12E	MD	D	Oxide from carbonate and bementite (1) Cal Div Mines R21:163; B76:31
13	Lavaginio	Steve Lavaginio	3	2N	13E	MD	D	Low-grade oxide (1)
	Manganese: see Harrington							
	Manilla: see Kellogg							
14	Pescia	Charles Pescia		4N	14E	MD	D	Spessartite and rhodonite (2)
15	Soapstone	E.C. Staples	18	4N	14E	MD	D	Spessartite (1)

CALAVERAS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	R. & M.		
16	Sunshine  Vanella: see Kellogg	C.S. Pierce					D	Active (3)
17	Zurcher	F.D. Zurcher (L.A. St. John, former lessee)		4N	14E	MD	D	Oxide from spessartite (2)

## COLUSA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sic.	T.	R.	B. & M.		
1	Burgett	D.W. Burgett	12	15N	6W	MD	D	Franciscan type (2)
2	Gullman	Arthur Gullman	1, 2 12	15N	6W	MD	D	Franciscan type (3)
3	Rathbun	J.P. Rathbun	4	17N	7W	MD	D	Franciscan type Cal Div Mines B38:335

## CONTRA COSTA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sic.	T.	R.	B. & M.		
1	Red Rock Island	U.S. Government (formerly Arthur B. Riehl and Louis H. Eilken)		1N	5W	MD	B	Franciscan type Cal Div Mines R23:16; R17:55; B76:31 Min Res U.S. 1882:424 Harder, E.C. (10) 164, 166, 271 Lawson, A.C. (14) 23 Penrose, R.A.F. Jr. (91) (490)

DEL NORTE COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
1	Siskiyou Fork Trail	Robert Stone	11	17N	3E	H	D	Oxide films on schist (3)
2	Stone		35?	18N	1E	H	D	Manganiferous chert (3)

## EL DORADO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Alderson	Mrs. Agnes Alder- son	16 17	10N	11E	MD	D	Cement in sandstone in- terbedded with Tertiary volcanics (2)
2	Buffalo Hill		10	12N	10E	MD	D	Oxide in mangiferous chert (3)
3	David	D. David	10	12N	10E	MD	D	Mangiferous chert (1)
4	Double E	Joseph Schuppl	12	9N	10E	MD	D	Mangiferous chert (2)
5	Martinez Gold	Martinez Gold Mines Company	NE13	9N	10E	MD	D	Rhodonite (1)
6	Mocettini	Philip Mocettini	13	8N	9E	MD	D	Manganese oxide stains on Greenstone (1)

## FRESNO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prop.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Avery	George D. Avery		21S	14E	MD	D	Undeveloped Cal Div Mines B76:32 Location approximate
2	Crisle	John Crisle	15	12S	24E	MD	D	Rhodonite (2)
3	Harper	W. J. Harper	NW33	11S	24E	MD	D	Rhodonite and spessartite (2)
4	McMurtry	W. F. McMurtry	33	11S	24E	MD	D	Rhodonite (1,2)
5	Price	J. W. Price	11?	12S	24E	MD	D	Rhodonite (2)
6	Sunset and Sunrise	V. R. Smith (G. E. Freme, former lessee)					C	Alcalde district (3)
7	Trewick	C. C. Trewick (J. B. and J. R. Houghton, for- mer lessees)	SW29	13S	26E	MD	D	Rhodonite (2)
8	Woods	"Jake" Rice		12S	24E	MD	D	Rhodonite Cal Div Mines B76:32



## GLENN COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	B. & M.		
1	Big Stony Creek (Rockridge)	E.J. Hansen ?	25 or 26	18N	7W	MD	D	Manganiferous chert (1)
2	Black Diamond (North Star)	A.W. Sehorn (A.H. Noyes, former lessee)	14,23	18N	7W	MD	C	Franciscan type Cal Div Mines R25:421; R16:198; B76:32
3	Brown and Moore	Brown and Moore	N 1	18N	7W	ML	D	Franciscan type (1)
4	B.S. No. 1	W.E. Sale Charles A. Butler	26	21N	8W	MD	D	Manganiferous chert in sericite schist (1)
5	Elephant Hill	Charles A. Butler Vesta Kellar		19N	7W	MD	D	(3)
6	Hummingbird	L.D. Stall H.A. Butler Raymond Butler	36	21N	7W	MD	D	Manganiferous chert in sericite schist (1)
7	K.B. No. 1	H.D. Bruce, Brown and Moore	S35	19N	7W	MD	D	Franciscan type (1)
8	K.B. No. 4	H.D. Bruce, Brown, and Moore (M.C. Syar, lessee)	N 1	18N	7W	MD	C	Active Franciscan type (1)
9	Levensaler and Speir	Levensaler and Speir Corp.					C	Loc. at Fruto (?) (3)
	Moore, Brown and: see Brown and Moore							

## GLENN COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S.E.	T.	R.	B. & M.		
10	North Star: see Black Diamond  Rattlesnake   Rockridge: see Big Stony Creek  Speir, Levensaler and; see Levensaler and Speir	Brown and Moore (formerly A.H. Noyes, H.B. Chase, and T. Norris)	SE 6	18N	6W	MD	C	Franciscan type (1,2) Cal Div Mines R25:421; B76:32

## HUMBOLDT COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	A. E. C.	Mrs. Dave Murphy		NE1S	4E	H	D	Franciscan. Mangan- iferous chert (2)
2	Burns	Burns, and C. W. Manning		SW1S	51	H	D	Franciscan. Oxide (2)
3	Charles Mountain (Woods, Haw)	L. Windbigler (F. M. Doak, James and Joseph Warren, lessees)	2, 11	1S	4E	H	E	Active Franciscan. Carbonate ore (1, 2) Cal Div Mines R21:319; B76:34
	Clinton M: see Martin and Murphy							
4	Fort Baker (Porter Ranch)	Russ Company (F. M. Doak, W. H. Haw, N. L. Bry- ant, former lessees)	32	3N	4E	H	B	Franciscan (1, 2) Cal Div Mines R21:319; B76:33
5	Fort Seward	Humboldt Land and Development Co. (F. M. Doak, for- mer lessee)	15	3S	4E	H	B	Franciscan. Braunite (1, 2)
	Haw: see Charles Mountain							
6	Janes Creek	N. H. Falk (W. M. Dawkins, former lessee)	21	6N	1E	H	D	Franciscan (1, 2)

HUMBOLDT COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				Class By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
7	Leaning Tree No. 2	T.O. Millett Mae Stinson J.L. Millett	NE 9	6N	4E	H	D	Low-grade; in green- stone (1)
8	Live Oak No. 1	Rohrbough Ranch	NW 6	4S	6E	H	D	Franciscan (1)
9	Martin and Murphy (Clinton M.)	Charles Martin Thomas Murphy		1S	5E	H	D	Franciscan (2)
10	Murphy  Murphy, Martin and; see Mar- tin and Murphy  Porter Ranch: see Fort Baker	Dave Murphy, and Jean	W 7	3S	6E	H	D	Franciscan (2)
11	Pryor No. 1	Pryor Ranch (Rae F. Helmke, lessee)	SW25	2S	5E	H	D	Franciscan (1)
12	Red Knoll	Charles Brewer					D	Near Fort Baker Franciscan Eng and Min Jour (18a)
13	Sam Brown (World War No. 2)	Sam Brown (W.A. Scott, lessee)	15	8N	4E	H	D	Rhodonite in recrystal- lized chert (1)

HUMFOLDT COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
14	Windbigler No. 1	L. Windbigler (James and Joseph Warren, lessees)	15	1S	4E	H	D	Franciscan (1)
15	Windbigler No. 2	L. Windbigler (James and Joseph Warren, lessees)	11	1S	4E	H	D	Franciscan (1)
	Woods: see Charles Mountain							
	World War No. 2: see Sam Brown,							

## IMPERIAL COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1			97	9S	20E	SB	D	Manganiferous conglomerate (1) North of Chocolate Drop
2	Anson	W. J. Anson					C	Location unknown - "Glamis" (2)
3	Chocolate Drop (Big Bear, Black Jack; Ebony group)	O. H. Tetzlaff (Mine Development Co., H. S. West, lessees)	9	9S	20E	SB	E	Active 1942 Fissure veins in conglomerate (1,2) Cal Div Mines R22:264; B76:34,35
4	Desert Bloom	Henry L. Jackson Edward Rochester	24	9S	20E	SB	D	Cal Div Mines R38:129
	Ebony Group: see Chocolate Drop							
	Everharty: see Whedon							
	Lincoln: see Pilot Knob							

## IMPERIAL COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
5	Lugo (Palo Verde)	T. Lugo P.D. McIntyre	35	9S	20E	SB	C	Fissure veins with cal- cite in andesite (1,2) Cal Div Mines R25:494; R22:265; R17:269; R15: 547; B76:59 Jones, E.L., Jr. (19) 185 200
6	MacDonald	Edward MacDonald	12	9S	20E	SB	D	Cal Div Mines R38:130
	Palo Verde: see Lugo							
	Paymaster district: see Whedon							
7	Pilot Knob, Lincoln, Well Earned	M.C. Turner		12S	19E?	SB	D	(3) Location unknown
8	Southern Pacific	Southern Pacific Land Company	E33	9S	20E	SB	D	Cal Div Mines R38:130
	Tolbard: see Whedon							
	Tres Amigos: see Whedon							
9	Turtle	E.D. Hodges	16	11S	21E	SB	D	Fissure vein Hadley, J.B. (42)
10	War Manganese	War Manganese Co. (C.R. and Ethel Zappone, Morgan Leshner)	19	11S	21E	SB	C	Fissure deposit in fan- glomerate (1) Active

IMPERIAL COUNTY - cont.

No.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
11	Well Earned: see Pilot Knob  Whedon (Paymaster district; Tolbard, Tres Amigos, Everhart, Curly M.)	V.B. Whedon	18, 19	11S	21E	SB	A	Fissure deposits in fan- glomerate, andesite, and granite (1, 2) Active Cal Div Mines R22:265, 266 Jones, E.L., Jr. (19) 185, 201, 206, 207



## INYO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	April Fool	Thos. Keegan J.D. Gray Ed Miley	33	21N	2E	SB	D	Bedded wad (?) deposit (2)
2	Black Dream (Wingate Wash)	Roy C. Troeger		20N	1E	SB	D	Probable location Fissure deposit in Ter- tiary conglomerate and sandstone (1)
3	Campbell	W.D. Campbell					D	Loc. "Death Valley" Fissure deposit (3)
4	Connard Bros.	Connard Bros.					D	Loc. 32 miles west of Zabriskie Small veins Cal Div Mines B76:36
5	Death Valley (Manganese 1 to 6)	E.P. Underwood E.G. Henderson					D	Same vicinity as Connard Bros. Small veins Cal Div Mines B76:36
6	Geronimo	Ben Grier		19S	38E?	MD	D	Small amount of manganese oxide in lava (3)
7	Lillie (Mature Cons.)	Mrs. Gertrude Morgan (former- ly Harold Chap- pelle)	14, 15 20, 21	23S	43E	MD	D?	Gossan in limestone; manganese oxide from gredrite and garnet rock (1, 2)
8	Manganese No. 1 and No. 4	Thos. Keegan J.D. Gray Ed Miley	33	21N	2E	SB	D	Fissure deposit (1)

## INYO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	E. & M.		
9	Manganese 1 to 6: see Death Valley							
	Mature Cons.: see Lillie							
	Orr	Frank W. Orr					D?	40 miles from Shoshone Bedded deposit ? (3)
10	Runge	Chris Runge		18S	38E	MD	D?	(3)
11	War Baby (Wingate Wash)	W.C. Davis C. Fleharty, Jr.		20N	1E	SB	D	Probable location Bedded deposit (1)
	Wingate Wash: see Black Dream, War Baby							

## KERN COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
1	Apache	Richard Hamilton		29S	36E?	MD	D	Oxide replacement in limestone (3)
2	Big Indian	W.W. King		30S	40E?	MD	D	Rhodonite ? (3)
3	Culbert	Culbert Bros.	10	30S	40E	MD	D	Spessartite and rhodonite (2)
4	Exposed Treasure		19 20?	11N	12W	SB	D?	Worked for gold De Kalb, C. (08) 310
5	Manganese Queen	L.J. Osborne or E.J. Emmons	16	30S	40E	MD	D	Rhodonite and spessartite (2)
6	Midlothian	M.J. Lovett	12	30S	39E	MD	C	Rhodonite and spessartite (2)
7	O.K.	F.V. Keough H.R. McAllister	27?	26S	34E	MD	D	Very large crystals of rhodonite (1)
8	Shamrock No. 2	Capt. R.H. Dymond E.R. Tabor Jack Boatwright M.J. Meadows	26	29S	40E	MD	D	Oxide from rhodonite ? (1)
9	Snowy No. 1	R.C. Cuddy, Sr.	12?	9N	21W	SB	D	Manganiferous chert (1)
10	Walsh and McCloud	W.J. Walsh		28S	39E	MD	D	(3)

LAKE COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				Class By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Arroyo Lobo	Chas. R. Dow	3	14N	7W	MD	D	Abandoned Franciscan oxide in chert (1,2)
2	Bell		31	12N	5W	MD	D	Franciscan oxide in chert (2)
3	Black Point	M.W. Clark	21	11N	8W	MD	D	Franciscan oxide in chert (2)
4	Black Powder	T.M. Smith	NE31	12N	5W	MD	D	Manganiferous iron ore in chert in greenstone (2)
	Black Rock: see Vann Ranch							
5	Cobb Mountain (Geyser Rock)	W.A. McCombs George Hill	Appr. 21	11N	8W	MD	D	Chert (2)
6	Coleman	J.H. Coleman J.D. Sullivan	.29	12N	9W	MD	D	Manganiferous chert (2) Cal Div Mines R25:343; B76:37
7	Copsey and Moore	Arthur Copsey W.P. Moore	33	12N	7W	MD	D	Manganiferous chert near greenstone (2)
8	Dow	Carol Dow	4	14N	7W	MD	D	Manganiferous chert (1)
9	Downey Estate	Downey Estate	NW8	10N	7W	MD	D	Franciscan oxide in chert (1)

## LAKE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
10	Ebenhauser	Frank Ebenhauser	20	12N	5W	MD	D	Manganiferous iron ore (2)
11	Elliot  Geyser Rock: see Cobb Mountain	Frank Elliot	25 or 26	12N	9W	MD	D	Manganiferous chert (1)
12	Gravelley Valley	E. George McCullough Bros. (formerly Wm. Leard)	3	18N	10W	MD	C	Active Franciscan oxide in chert (1,2)
13	Grizzly Canyon: see Vann Ranch  Hermann	Henry Hermann	20	11N	5W	MD	D	Manganiferous iron ore (2) Cal Div Mines R25:343; B76:37
14	Herndon (Manganese No. 1)	N.W. Herndon	22	14N	6W	MD	D	Manganiferous iron ore (2)
15	Herriok	S.B. Herriok	25	11N	8W	MD	D	Chert (2) Cal Div Mines R25:343; B76:37

LAKE COUNTY - cont.

No.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
16	LaBree (Manganese No. 2)	Jack LaBree	22	14N	6W	MD	D	Chert (2)
17	Little Falls	James Cunn, Jr.	25	12N	9W	MD	D	Chert (1)
18	M and G	Jack LaBree L. Evans	34	14N	7W	MD	D	Chert (2)
19	Manganese No. 1: see Herndon	Ray Mead	35	11N	8W	MD	D	Chert (1)
	Manganese No. 2: see LaBree							
	Middle Creek; see Vann Ranch							
20	Moore, Copsey and: see Copsey and Moore	Ben F. Myers Mrs. T. D. Myers	35	13N	6W	MD	D	Manganiferous iron oxide (2)
	Myers (Red Bay)							
	Old Dough							
21		J.E. Rees		12N	9W	MD	D	Cal Div Mines R25:343; R17:78
22	Ora Hans	Ora Hans	20	12N	5W	MD	D	Manganiferous iron ore (2)
23	Overlook	J.D. O'Brien R.C. Miller	33	13N	10W	MD	D	Manganiferous iron ore (2)

## LAKE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
24	Phillips	W.S. Phillips (Lew Thorne and Son, former lessees)	16	15N	10W	MD	B	Franciscan oxide in chert (1,2) Mined out? Cal Div Mines R25:343; R17:78
25	Rainbow Ledge	O.H. Tyrer, and Erskine	NW35	15N	10W	MD	D	Franciscan oxide in chert (1)
26	Rattlesnake	O.E. Hermann	29	11N	5W	MD	D	Manganiferous iron ore in Greenstone (2) Cal Div Mines R25:343; B76:37
	Red Bay: see Myers							
27	Rose Ranch	F.H. Rose	10	15N	9W	MD	D	Chert (1)
28	Smythe	Ormsby Ranch		10N	7W	MD	D	Franciscan oxide in chert (2) Cal Div Mines R25:343; R17:79
29	Spring Hill	R. Peterson	Appr. 30	11N	7W	MD	D	Float (2)
30	Summit	A.H. Hoyt	2 or 11	13N	11W	MD	D	Franciscan oxide in chert (1)
31	Vann Ranch (Middle Creek, Black Rock, Grizzly Canyon)	G.W. Vann (Holbrook and Burris, former lessees)	34	17N	10W	MD	C	Chert (1,2) Cal Div Mines R25:343; R17:78; B76:37

LAKE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
32	Von Glahn	Henry Von Glahn	SW 5	10N	7W	MD	C	Franciscan oxide in chert (1)
33	Witter Springs	Witter Medical Springs, Inc. (Blake Bros., former lessees)	32	16N	10W	MD	D	Considerable neotocite (2)



## LOS ANGELES COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Amargosa group: see Black Bros., Red Feather Black Bros. (part of Amargosa group, Llewellyn Iron)	Black Bros.?	NE30?	6N	12W	SB	D?	Rhodonite deposit (1) Cal Div Mines R33:199; R23:317; R17:320; R15: 478; B76:38
2	Gladwin and Peet Llewellyn Iron: see Black Bros., Red Feather Peet, Gladwin and: see Gladwin and Peet	G.L. Gladwin H.G. Peet	36	6N	14W	SB	D	Rhodonite deposit Cal Div Mines B76:38
3	Purple Sage	Clarence Cruzan	NE 7 SW 5	5N	14W	SB	D	Rhodonite deposit (1)
4	Red Feather (part of Amargosa group, Llewellyn Iron)	H.E. LaFrentz M.M. LaFrentz (G.T. Humphreys, lessee)	24	6N	13W	SB	B	Rhodonite deposit (1) Cal Div Mines R33:199; R23:317; R17:320; R15: 478; B76:38

## MADERA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				Class by Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Agnew Meadows	Charles Summers (Dr. H.A. Stephens, for- mer lessee)		center 3S	26E	MD	D	Rhodonite - rhodochrosite (1)
2	Hazelton and Kennedy  Kennedy, Hazelton and: see Hazelton and Kennedy	J.W. Hazelton W.C. Kennedy	28	9S	22E	MD	D	Rhodonite and spessar- tite (2)
3	Krohn  Nuss, Stewart and: see Stewart and Nuss	H.A. Krohn	22	7S	21E	MD	D	Rhodonite (2)
4	Scott	S.A. Scott					D	Locality unknown (3)
5	Stewart and Nuss	George Teaford Otis Teaford	1 or 2	8S	21E	MD	D	Low grade spessartite and rhodonite (1)
6	Thornberry	S.A. Vaneman		7S and 8S	21E and 22E	MD	D	Manganese stains on quartzite (3)

## MARIN COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sic.	T.	R.	B. & M.		
1	Fort Baker			1S	6W	MD	D	Location approximate Typical Franciscan de- posit Cal Div Mines R22:321; B76:39 Lawson, A.C. (14) 23
2	Knutte	Connell and Brazil (L.R. Knutte, lessee)	NW19	3N	6W	MD	D	Typical Franciscan de- posit (1) Active
3	Mailliard Ranch	Lagunitas De- velopment Co.	Appr. 13	2N	8W	MD	D	Manganiferous chert Cal Div Mines R22:320; R14:249; R13:506; R12: 329; R11:253; B76:38
4	Mazza	R. Mazza	SW28	4N	7W	MD	D	Typical Franciscan de- posit (2)
5	Petaluma - Point Reyes		30	4N	7W	MD	D	Typical Franciscan de- posit (2)
6	Sausalito Point			1S	6W	MD	C	Typical Franciscan de- posit Location approximate Cal Div Mines R22:320 Harder, E.C. (10) 164, 272 Penrose, R.A.F., Jr. (91) 489

## MARIPOSA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sic.	T.	R.	B. & M.		
1	Caldwell (Daly)  Camin, Mebold and: see Strickland  Daly: see Caldwell	C.C. Caldwell et al (Walter Hixon, lessee)	NE14	3S	15E	MD	B	Manganocalcite (1,2) Active
2	Donnelly (Gerrior)	J.C. Donnelly	17?	4S	19E	ML	D	Rhodonite (1,2)
3	Gale  Gerrior: see Donnelly	W.T. Gale	1	3S	15E	MD	D	Manganese oxide stains in chert (1)
4	Kelm  M and Q: see Surprise	H.J. Kelm Allebrand Min- erals Company	19	3S	16E	MD	D	Oxide derived from rhodonite ? (1) Active
5	Robie  Mebold and Camin: see Strickland	John L. Robie	2	3S	15E	MD	D	Oxide derived from rhodonite (1)
6	Strickland (Mebold and Camin)	Mrs. Anna Strickland	8	4S	19E	MD	D	Some rhodonite (1,2)
7	Surprise (M and Q)	E.B. Pine	E23	3S	17E	MD	D	Rhodonite, rhodochrosite, and spassartite (2) Cal Div Mines R24:123

## MENDOCINO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prop.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Ash Hollow	W.H. Fitzhugh		SW24N	12W	MD	D	Manganiferous obert (2)
2	Bevins-Busch (Lee, Potter Valley)	S.H. Busch J.J. Busch A.P. Bevins	3, 10	17N	12W	MD	B	Typical Franciscan deposit (2) Cal Div Mines R25:463; R17:145; B76:40
3	Big Bend	C.V. Ereton W.E. Shields M.G. Morrison J.D. Morrison	28	23N	11W	MD	D	Mostly float (2) Cal Div Mines B76:40
	Big Jim: see Consolidated							
	Black Leases: see Consolidated							
	Blands Cove: see McLaughlin							
4	Ereton (New Year, Old County)	Mrs. J.Q. White (C.W. Hymer and L.E. Rufener, former lessees)	31 32	23N	11W	MD	C	Carbonate ore; oxide mined out (1,2) Cal Div Mines B76:46
5	Buck Ridge	C.B. Walsh B. Mendenhall	17	15N	11W	MD	D	Typical Franciscan deposit (2)
	Busch: see Foster Mountain							
	Busch, Bevins-: see Bevins-Busch							

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
6	Gallizo	S.V. Fromme	33	13N	12W	MD	D	Typical Franciscan deposit (1)
7	Cinco De Mayo	C.V. Brereton M.G. Morrison W.H. Foster	27	24N	11W	MD	D	Carbonate ore (2)
8	Cleveland (Homestead)	R.L. Cleveland	13	16N	12W	MD	D	Typical Franciscan deposit Cal Div Mines R14:421; B76:42
9	Consolidated (Black leases, Big Jim, Lone Indian, Mount San- hedrin)	A.C. Hauer W.R. Hubbard	30	20N	11W	MD	C	Typical Franciscan deposit (1,2) Cal Div Mines B76:45
10	Cooper	F.M. Cooper	33	12N	11W	MD	C	Contains neotoolite (1)
11	Coursey Bros.	J.W. Coursey J.F. Coursey C.M. Coursey (J.E. Page, former lessee)	4	18N	13W	MD	D	Manganiferous chert (2)
12	Dorn	C.A. Dorn (J.E. Page, former lessee)	SE28	19N	12W	MD	D	Typical Franciscan deposit (2)
13	Faucher	Mrs. G.P. Beck	22	17N	12W	MD	C	Typical Franciscan deposit (2)
14	Fischer	Herman Fischer	9	17N	12W	MD	D	Typical Franciscan deposit (2)

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Paob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
15	Fisher	A. Fisher	9	17N	12W	MD	D	Typical Franciscan deposit (2)
16	Foster Mountain (Independent, Busch, Lucky Boy)	Car-Gor-Van Co. (J.E. Page, former lessee)	3 or 4	18N	12W	MD	A	Active Typical Franciscan deposit (1,2) Cal Div Mines R25:463; R17:145; B76:42
	Fredriola: see Heughes							
17	Graham	Mrs. Vollie Graham		20N	14W	MD	D	Typical Franciscan deposit (3) Very small
	Guthrie: see Spy Rock							
18	Hale	Mrs. Fred Hale	24	12N	11W	MD	D	Typical Franciscan deposit (1)
	Happy Four: see Long, Earl W.							
19	Harms	Henry Harms	34	19N	12W	MD	D	Active Typical Franciscan deposit (1)
20	Heughes (Fredriola)	Mrs. Effie M. Heughes	27	17N	12W	MD	D	Typical Franciscan deposit (2)
21	Hinriols	A. Hinriols	SW22	19N	12W	MD	D	Typical Franciscan deposit (2)

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				Class By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
	Homestead: see Cleveland							
22	Hopper		16	17N	11W	MD	D	Manganiferous chert (2) Cal Div Mines B76:44
	Hurt, Rhodes and: see Rhodes and Hurt							
23	Impassable Rock (Rhodochrosite, Mount San- hedrin)	O. Haslett L. Winchel M. Woodward	31	20N	11W	MD	D	Considerable carbonate exposed at surface (1,2) Cal Div Mines B76:44
	Independent: see Foster Mountain							
24	Jumpoff Creek	Elmer Bauer	32	23N	10W	MD	D	Typical Franciscan de- posit (1,2)
25	Knight	Mrs. Mamie Knight	30 25	18N or 18N	13W 14W	MD	D	Typical Franciscan de- posit (1)
	Last Chance: see Long, Earl W.							
26	Leap	H. Leap	11	22N	15W	MD	D	Manganiferous iron ore (2)
	Lee: see Bevins-Busoh							



## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROB.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
27	Leeoh Lake Mountain, Line Gulch	C.V. Brereton M.G. Morrison	16 or 21	24N	11W	MD	D	Typical Franciscan deposit (2) Cal Div Mines B 76:44
28	Leona	J.L. Taylor et al. (Wm. Pickle former lessee)	NE27	17N	12W	MD	C	Typical Franciscan deposit (2)
29	Liberty  Line Gulch: see Leeoh Lake Mountain	F.W. Keeney	SW15	17N	12W	MD	D	Typical Franciscan deposit (2)
30	Linser  Lone Indian: see Consolidated	Chester Linser (Rae F. Helmke, lessee)	32	5S	5E	H	B	Active. Much landslide material (1)
31	Lone Tree	W.S. Graham	20	14N	11W	MD	D	Float (2)
32	Long, Earl W. (Woodman Station, Happy Four, Last Chance)	John W. Vinton Douglas MacMillan	12	22N	14W	MD	D	Typical Franciscan deposit (1,2) Cal Div Mines RI7:146
33	Long, F.J.  Lucky Boy: see Foster Mountain  Matthews, Shaw and: see Shaw and Matthews	Terry	1	24N	14W	MD	D	Typical Franciscan deposit (1,2)

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			S. C.	T.	R.	B. & M.		
34	McClendon	Walter McClendon	Appr. 1	16N	12W	MD	C	Typical Franciscan deposit Cal Div Mines B76:44
35	McLaughlin (Blands Cove)	D.D. McLaughlin	26	24N	11W	MD	D	Typical Franciscan deposit (2) Cal Div Mines B76:40
36	Michaels, Roman, and Weeks	Chas. Brereton	30	23N	11W	MD	D	Typical Franciscan deposit Cal Div Mines B76:44
37	Montezuma Improvement Co.	Montezuma Improvement Co.		23N	14W	MD	D	Manganiferous chert (2)
38	Morrison  Mount Sanhedrin: see Consolidated, Impassable Rock  New Year: see Brereton	M.G. Morrison	1	22N	12W	MD	D	Typical Franciscan deposit (2)
39	Nowlin	Laine Tilford W.L. Tilford Edith Kellogg Von Kronskey	3	22N	13W	MD	B	Typical Franciscan deposit (1,2)
40	Ocean View  Old County: see Brereton	Henshaw Ranch	NE34	20N	12W	MD	D	Manganiferous iron ore (2)

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	B. & M.		
41	Pieta Creek: see Pine Mountain							
	Pine Mountain (Pieta Creek)	C.R. Adams Mrs. Larson	25,26	12N	10W	MD	D	Bementite ore (1) Cal Div Mines R17:146
	Potter Valley: see Bevins-Busch							
42	Rhodes and Hurt	W.D. Rhodes G.H. Hurt	36	23N	12W	MD	D	Float (2) Cal Div Mines B76:46
43	Rhodochrosite: see Impassable Rock							
	Roman: see Michaels, Roman, Weeks							
	Rose	J.B. Keaster D. Rose	21	20N	14W	MD	C	Typical Franciscan deposit (1,2)
44	Round Mountain: see Thomas							
	Rowlison	J.S. Rowlison		20N	13W	MD	D	Landslide? (1)
	Saling	J.M. Saling	SW13	13N	11W	MD	D	Typical Franciscan deposit (1)
46	Scott	Mrs. C.H. Scott	NE10	18N	12W	MD	D	Typical Franciscan deposit (2)

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
47	Shaw and Matthews	F.M. Cooper	33	12N	11W	MD	C	Typical Franciscan deposit (1,2) Cal Div Mines R22:338; R14:333; R13:507; R12: 330; R10:675; B76:83; B38:337 Harder, E.C. (10) 163
48	Shell Rock	(Noble Electric Steel Co., for- mer lessee)		23N	15W	MD	D	Typical Franciscan deposit Cal Div Mines B76:46
49	Skaggs Springs	(Noble Electric Steel Co., for- mer lessee)					C	Typical Franciscan deposit (2)
50	South Thomas	W.P. Thomas J.R. Thomas W.H. Travers	NE27	17N	12W	MD	A	Typical Franciscan deposit (1,2)
51	Spy Rock (Guthrie)	Geo. W. Read Co. (formerly Jim Ray)		23N	15W	MD	D	Typical Franciscan deposit (2) Cal Div Mines B76:46
52	Star	M.G. Morrison W.H. Foster C.V. Brereton	25	24N	11W	MD	D	Typical Franciscan deposit (2)
53	Summer Camp	Henshaw Ranch	27	20N	12W	MD	D	Manganiferous iron ore (2)
54	Thatcher Creek	Lige Shields W.E. Shields C.C. Packwood (Michaels, Ro- man, and Weeks, former lessees)	23	21N	11W	MD	D	Manganiferous iron ore (2) Cal Div Mines B76:46

## MENDOCINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
55	Thomas (Round Mountain)	W.P. Thomas J.R. Thomas (Noble Electric Steel Co., for- mer lessee)	22,27	17N	12W	MD	A	Reserves mainly oar- bonate (1,2) Cal Div Mines R25:436; R17:145; R14:421; B76: 46 Dolbear, S.H. (15) 174 Harder, E.C. (10) 163 Min Ind v25:491
56	Two Trees	J.D. Morrison G.H. Brereton	NW32	24N	10W	MD	D	Typical Franciscan de- posit (2)
57	Ukiah						C	Typical Franciscan de- posit (3)
58	Usal	Sage Land and Development Co., Crocker Natl. Bank	1,2 26 35,36	23N 24N 24N	18W 18W 18W	MD	D	Manganiferous iron ore replacing limestone (1)
59	Wild Devil	Waldeufel Bros. J.B. Richardson (Noble Electric Steel Co., for- mer lessee)	N 15	17N	12W	MD	B	Typical Franciscan de- posit (1,2) Cal Div Mines R25:463; R17:145; B76:48
60	Wishbone	J.B. Keaster D.C. Rose		20N	14W	MD	D	Typical Franciscan de- posit (1)
61	Woodman Station: see Long, Earl W. Young	Fred Young C.R. Young (J.E. Page, for- mer lessee)	28	19N	13W	MD	D	Typical Franciscan de- posit (1,2)

MERCED COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Briggs	Mrs. Briggs (M.M. Grayson, former lessee)	13	13S	9E	MD	D	Manganiferous oher (1,2) Cal Div Mines R21:181; R17:150; R14:606; B91: 124; B76:49; B38:335

## MONO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROG.	REMARKS AND REFERENCES
			Sec.	T.	R.	B & M.		
1	Black Horse	R. J. Thomas R. Frederickson Bert Davis	N 8	6N	25E	MD	D	Small stringers of psilomelane. Fissure deposit (1)
2	Champion	George Moyle	25	4N	25E	MD	D	Fissure deposit (1)
	Manganese No. 1: see Taylor							
3	Miami	L. A. Murphy W. A. McRae	1	3N	25E	MD	D	(2)
4	Mono Manganese No. 7	J. L. Wade	1	3N	25E	MD	D	Small stringers of psilomelane. Fissure deposit (1)
5	Penrose	Jack Penrose		7N	25E	MD	D	Limonite and wad (3)
6	Taylor (Manganese No. 1)	George Moyle (W. B. Taylor, lessee)	NW13	3N	25E	MD	C	Active Fissure zone in vol- canics (1)

MONTEREY COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prop.	REMARKS AND REFERENCES
			Sr. C.	T.	R.	B. & M.		
1	Evans	W. J. Evans J. C. Evans	SW24	24S	6E	MD	D	Typical Franciscan de- posit (2)
2	Ross Ranch	J. Dutra Ross	31?	24S	6E	MD	D	Cal Div Mines B76:50 Typical Franciscan de- posit
3	Wayland Ranch	Wayland Ranch	E 9	22S	13E	MD	D	Manganese oxide films on chert (2) Typical Franciscan de- posit



## NAPA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLAIM By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Adams and Westendorf	Thomas Adams P.J. Adams	32	11N	4W	MD	D	Franciscan type. Man- ganiferous iron ore (2)
2	Bacon and Kenney	F.W. Kenney Thomas Bacon	19	7N	5W	MD	D	Franciscan type (2) Cal Div Mines R25:219; R14:276; B76:51
3	Blue Monday (Searchlight, Surprise)	R.A. Dollarhyde J.W. Charge W.R. Hanson Henry Hermann	8	10N	4W	MD	D	Franciscan type. Man- ganiferous iron ore (2)
4	Cavagnaro	Chas. Cavagnaro	3	9N	6W	MD	D	Franciscan type. Man- ganiferous iron ore (2) Cal Div Mines R25:219; B76:51
5	Conn Valley		2	7N	5W	MD	D	Franciscan type Cal Div Mines 12:329
6	Hastings  Jacobson, Ries and: see Ries and Jacobson  Kenney, Bacon and: see Bacon and Kenney	Lyle Hastings					D	$\frac{1}{2}$ -mile S. 36° W. from Snell Peak (3) Franciscan type
7	Lewis	Allen Lewis Glenn C. Griffen	SE20	9N	4W	MD	D	Franciscan type. Mangan- iferous ore in green- stone (2)

## NAPA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
8	Liberty	G.E. Tarry	NE31	10N	5W	MD	D	Franciscan type. Man- ganiferous chert in greenstone (2)
9	Lombardi	Paul Lombardi	13	10N	5W	MD	D	Franciscan type. Man- ganiferous iron ore (2)
	Manganese Ridge: see Moore Creek							
10	Moore Creek (Manganese Ridge)	G.E. Wolcott	15	8N	5W	MD	B	Franciscan type (2) Cal Div Mines 25:219; B76:51
11	Nichelini	A. Nichelini	33	8N	4W	MD	D	Franciscan type. Man- ganiferous chert (2)
12	Powers	G.B. Powers	29	8N	4W	MD	D	Franciscan type (2)
13	Ries and Jacobsen	R.M. Ries Oscar Jacobsen	18	10N	5W	MD	D	Franciscan type (2)
	Searchlight: see Blue Monday Surprise: see Blue Monday							
14	Wallace	G.P. Wallace	13	9N	5W	MD	D	Franciscan type. Man- ganiferous iron ore (2)

## NEVADA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Arnold Bartholf and Veach: see Ryan	Max P. Arnold	5	14N	8E	MD	D	Rhodonite deposit Active (1)
2	Black Ledge	J.H. Pastland Lavina Richards	12	15N	9E	MD	D	Rhodonite deposit (2)
3	Black Squirrel	J.C. Talbot					D	Loc. on Bear River Ridge Rhodonite deposit (2)
4	Gleason	Gleason (C.A. Neville, former lessee; C.C. Stearns, D.F. Owens, lessees)	29	14N	8E	MD	D	Rhodonite deposit (1) Active
5	Good Enough 1 and 2	Wm. Rose	N9	16N	8E	MD	D	Rhodonite deposit Cal Div Mines R37:441
6	Manga-Chrome	Dan Duggan (C.A. Neville, former lessee; C.C. Stearns and D.E. Owens, lessees)	S17	14N	8E	MD	B	Rhodonite deposit (1) Active
7	Mangatop (Wren Ranch)	R.M. Wren	20	14N	8E	MD	C	Rhodonite deposit (2) Cal Div Mines R16:262; B76:51
8	McCarty	Jack McCarty		16N	10E	MD	D	Rhodonite deposit (3) Location approximate

## NEVADA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
9	Mebam	J.R. Mebam Bob Cole	9	14N	8E	MD	D	Rhodonite deposit (1)
10	Paine Bros.	D.R. Paine	NW15	17N	9E	MD	D	Rhodonite deposit. High in iron (1)
11	Pharo	W.H. Pharo	8	14N	8E	MD	D	Rhodonite deposit (1)
12	Ryan (You Bet, Bartholf and Veach)	Buck Ryan (J.M. Gross, lessee)	12	15N	9E	MD	B	Rhodonite deposit (1) Active Cal Div Mines RL6:262; B76:51
13	Santo	J.A. Santo	N1/	14N	8E	MD	D	Rhodonite deposit (1)
14	Smith	George A. Smith	32	14N	8E	MD	D	Rhodonite deposit (1) Active
15	Thompson	H.L. Thompson	17	14N	8E	MD	D	Rhodonite deposit (2)
	Wren Ranch: see Mangatop							
	You Bet: see Ryan							

## PLACER COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	B. & M.		
1	American; see Randel No. 1							
	Cape Horn	Daniel Russell	35	15N	9E	MD	D	Rhodonite Cal Div Mines B38:336 Harder, E.C. (10) 165 Penrose, R.A.F., Jr. (91) 495
	Coplen group, Tilsley and: see Gold Hill, Randel No. 1 Crown Point: see Gold Hill							
2	Emma	George Duncan	N28	14N	10E	MD	D	Rhodonite (2)
3	Gold Hill (Crown Point, part of Tils- ley and Coplen group)	H.R. Stone Sue H. Eaves	20	14N	10E	MD	C	Rhodonite (1) Active Cal Div Mines R23:283; B76:52
4	Gray lease: see Pettigrew- Stafford lease							
	Lee: see Yankee Jim							
	Lloyd	E.H. Lloyd	SE20	14N	9E	MD	D	Cement in chert breccia (1)

## PLACER COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
5	Pettigrew-Stafford lease (Gray lease)	Southern Pacific Land Co. (Pettigrew-Stafford & Co., lessee)	NE29	14N	10E	MD	D	Rhodonite (1) Cal Div Mines R23:283; B76:52
6	Randel No. 1 (American, part of Tilsley and Coplen group)  Stafford lease, Pettigrew- see Pettigrew-Stafford lease  Tilsley and Coplen group: see Gold Hill, Randel No. 1	E.V. Delmue	SW20	14N	10E	MD	C	Rhodonite (1) Cal Div Mines R23:283; B76:52
7	Yankee Jim (Lee?)	D.W. Lee ?		14N	10E?	MD	D	Rhodonite (2) Cal Div Mines R23:283

## PLUMAS COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLAIM BY PROB.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
1	Barrington: see Benner, Barrington, and Crabtree	Benner, Barrington, and Crabtree					C	Mainly rhodonite and bementite (3) Active
2	Brato (Iron Dyke, Feather River, Dixie Creek)	Al Timmins (Western Manganese Company, lessee)	27	26N	9E	MD	A	Braunite in fissure zone Active (1,2) Cal Div Mines R33:142; R16:179; B105:184; B103:184; B76:53 Min Res U.S. 1930:305; 1929:282; 1917:683
3	Buroh and Woody	A. Buroh	NW28	26N	9E	MD	C	Mainly rhodonite and bementite (2) Cal Div Mines R16:179; B76:53
4	Cannon	F.W. Bradley A.C. Wear	NW 6	25N	10E	MD	D	Mainly rhodonite and bementite (1)
5	Chrome Iron: see Valley View Crabtree: see Benner, Barrington, and Crabtree Crescent Mills: see Valley View Crystal Lake (Mount Hough, Myton and Kloppenburg)	George Holloway Ben Egbert	NW 8	25N	10E	MD	A	Mainly rhodonite and bementite (1,2) Active Cal Div Mines R33:143; R16:179; B76:53

## PLUMAS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
6	Diadem Lode: see Sierra Mangane							
	Dickie Bird		28	26N	9E	MD	C	Mainly rhodonite and bementite (1)
	Dixie Creek: see Braitto							
	Feather River: see Braitto							
7	Iron Dyke: see Braitto							
	Iron Queen	A.F. Smith C. DeVetter	7,8	26N	9E	MD	D	Mainly rhodonite and bementite (1) Cal Div Mines R16:180; B76:54
	Kloppenburgh, Myton and: see Crystal Lake							
	Lake View: see Valley View							
8	Liberty	James Shaw	14,15	25N	10E	MD	D	Mainly rhodonite and bementite (2)
	Lost Soldier	F. Bear J.L. Groves C.A. Asham A.M. Barton	NW 6	25N	10E	MD	D	Mainly rhodonite and bementite (1)
9	Mount Hough: see Crystal Lake							
	Mustang: see Valley View							



## PLUMAS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			S.E.	T.	R.	B. & M.		
10	Myton and Kloppenburg: see Crystal Lake  Penrose Lode			24N	8E	MD	D	Probably superficial manganese oxide Cal Div Mines R16:180; B76:54 Harder, E.C. (10) 164 Turner, H.W. (98)
11	Red Point: see Sierra Man- ganese  Rush Creek  Shaw, West and: see West and Shaw	C.W. Hymer					D	Mainly rhodonite and bementite (3)
12	Sierra Manganese (Diadem Lode, Red Point)	Edman Estate	33	24N	8E	MD	D	Mainly rhodonite and bementite Cal Div Mines R16:180; B76:53
13	Sunset	W.J. McMillan A.E. Williamson	SW 3	26N	8E	MD	D	Mainly rhodonite and bementite (1) Cal Div Mines R33:143
14	Valley View (Lake View, Mustang, Chrome Iron, Crescent Mills)	Contested	27	26N	9E	MD	C	Mainly rhodonite and bementite (1)
15	West and Shaw  Woody: see Euroh and Woody	N. West J. Shaw	26, 27	26N	11E	MD	D	Mainly rhodonite and bementite (2)

## RIVERSIDE COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	B. & M.		
1	Arentz-Perkins: see Langdon							
	Arlington (Ironwood district; Black Jack, Black Horse, Social, Bray, Melville, Parsons, Groce, Red Rock, Schellen- ger)	Fred Kroger (A.B. Miner et al., lessees)	13,24 19	4S 4S	19E 20E	SR SB	A	Fissure deposits in Tertiary volcanics Active (1,2) Cal Div Mines R25:492, 494; R17:328; R15:545, 546; B76:54,58 Jones, E.L., Jr. (19) 185, 193
	Beal-McClellan (Newport, Black Eagle)	G.S. Beal R.W. McClellan	SW23	5S	4W	SB	C	Bedded rhodonite in chert in Triassic (?) slates (1,2) Active Cal Div Mines R31:515; R25:493; R15:546; B76:56
2	Black Eagle: see Beal- McClellan							
	Black Horse: see Arlington							
	Black Jack: see Arlington							
3	Box Canyon (Shaver Well)	Lelon Noblitt	24	6S	10E?	SB	D?	(3)
	Bray: see Arlington							
	Brown, Mabery and: see Langdon							
4	Cheeseborough: see Langdon							

RIVERSIDE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
4	Clark and Losekamp Dioxide group: see Langdon	Clark and Losekamp		SW53	1W	SB	D	Oxide in shale and quartzite (3)
5	Doran	W.C. Doran	197	4S	18E	SB	D	Fissure deposit, inaccessible Cal Div Mines R25:493; B76:57
6	Elsinore	Chas. P. Carter	23,24	5S	4W	SB	D	Probably bedded rhodonite in chert in Triassic (?) slates Cal Div Mines R25:493; R15:546; B76:58; B38:336 Harder, E.C. (10) 165
7	Giant Chief  Groce: see Arlington  Hauser: see Langdon  Ironwood district: see Arlington	Solomon Ally Paul Ducker Miss Daisy; or C.M. Houser Charles McLaughlan (disputed)		E 3S	20E	SB	D	Stratifications and veinlets in limestone (1)

## RIVERSIDE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
8	Langdon (Dioxide group, Mabery and Brown, Arentz-Perkins, Hauser-Martin-Cheeseborough)	C.M. Langdon U.S. Gypsum Corp. (Francis Gage, lessee)	8	4S	21E	SB	A	Segregations and veins in brecciated limestone To become active? (1,2) Cal Div Mines R25:493, 494; R17:328; B112:156; B111:283; B103:184; B102:178; B76:58, 59 Jones, E.L., Jr. (19) 185, 193, 199
	Losekamp: see Clark and Losekamp							
	Mabery and Brown: see Langdon							
	Martin: see Langdon							
	Melville: see Arlington							
9	Mountaineer	Mountaineer Mining Company (Hugh Gordon, Pres.; H.H.B. Carter, lessee)	31	1S	24E	SB	D	Manganese oxide with gold and copper in fis- sure in limestone (1)
10	Newport: see Beal-McClellan							
10	Paddy Faulkner	Herman Kiel	23S	20E	20E	SB	D	Segregations and vein- lets in limestone (1)
11	Palen Mountains	Frank Coffey	4S	18E	18E	SB	D	Fissure deposit, inac- cessible Cal Div Mines R25:494; B76:59 Location approximate

## RIVERSIDE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			S. C.	T.	R.	B. & M.		
12	Parsons: see Arlington							
	Perkins, Arentz-: see Langdon							
	Pinkham	Chester A. Pink- ham	24 29, 30 32, 33	6S 6S	10E 11E	SB SB	D?	Float (3)
	Red Rock: see Arlington							
	Schellenger: see Arlington							
	Shaver Well: see Box Canyon							
	Social: see Arlington							

## SAN BENITO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sr.c.	T.	R.	B. & M.		
	Cleveland: see Hendricks							
1	Chambers	T.H. Chambers	S 11	18S	9E	MD	D	Typical Franciscan deposit. Manganiferous chert in San Andreas fault zone (1)
2	Fries Ranch	Ramon Samovia	5,8	13S	8E	MD	D	Typical Franciscan deposit. Bementite (1) Cal Div Mines R22:238; R15:644; B76:59
3	Hannagan	J. Hannagan	22	15S	9E	MD	C	Cal Div Mines R22:238; B76:60 Typical Franciscan deposit
4	Hawkins	T.S. Hawkins (John Burmeister, lessee)	35	11S	6E	MD	B	Typical Franciscan deposit. Oxide; adjacent to glaucophanous schist (1,2) Cal Div Mines R22:238; B76:60
5	Hendricks (Cleveland)	John Burmeister Mrs. Briggs L.E. Thornton (Cecil Smith and Roy Harris, lessees)	24	13S	8E	MD	D	Typical Franciscan deposit. Carbonate and bementite (1,2) Cal Div Mines R22:238; R15:664; R12:330; B76:60; B38:336

## SAN BENITO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				Class By Prod.	REMARKS AND REFERENCES
			Sfc.	T.	R.	B. & M.		
6	Lewis	W. Lewis	7	13S	8E	MD	D	Typical Francoisan deposit Cal Div Mines R22:238; R15:645; B76:61
7	McCreary Ranch	McCreary Ranch (R.R. Stephenson, lessee)	S29	14S	9E	MD	D	Francoisaoan oxide Active (1)

## SAN BERNARDINO COUNTY

NO	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Andreen	H.M. Andreen	18	8N	6E	SB	D	(2)
2	Big Reef (Black Butte)	C.S. Van Doren (M.R. Fisher, lessee; formerly H.W. Hess)	10	8N	6E	SB	C	Pirasure in andesite Active (1) Cal Div Mines R36:241
3	Black Beauty 1,2,3,4,5	R.A. Koontz W.H. Kimball, Jr. H.E. Ellis		15N	6E	SE	D	(3)
	Black Butte: see Big Reef							
	Black Chief: see Dawson							
	Black Magio: see Emma							
4	Black Mountain (Gallagher)	T.E. Gallagher J.W. Arrington	17,20	10N	22E	SB	D	Oxide lenses in granite- gneiss (2)
5	Black Prince (Manganese Cliff, Manganese King)	C.S. Van Doren C.E. Burckhardt	4, 5	17N	4E	SB	D	Small veins in brecciated andesite Cal Div Mines B76:61
6	Black Raven (Lankin)	Hans von Lankin	4	8N	3E	SR	D	Black calcite in shear zone in volcanics (2)
7	Black Stone	J.H. Massen	28	11N	6E	SB	D?	Manganese oxide lenses on contact of granite and limestone Cal Div Mines R27:337; R17:354



SAN BERNARDINO COUNTY - cont.

NO	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			S.E.	T.	R.	B. & M.		
8	Dawson (McDowell, Black Chief)	J.H. Dawson (formerly E.W. McDowell)	32 or 33	4N	26E	SB	D	Fissures in basalt (1) Cal Div Mines R17:355 Jones, E.L., Jr. (19) 185, 189
9	Emma (Black Magic)	Harry Nasland and associates	16	18N	3E	SB	B	Fissure deposit. Man- ganese oxide in breccia of limestone. Active (1,2) Cal Div Mines R27:337; R17:354; R15:822; B105: 184; B107:181; B76:62 Min Res U.S. 1923:282; 1929:282; 1930:305; 1931:160
10	Lee Yim (Garringer, Lavio Mountain, Manganese 1-10)	L.W. Yim A.N. Rabe (J.M. Elmer and Walter W. John- son, lessees)		8N	7E	SB	C	Fissures in brecciated rhyolite Active 1942 (1,2) Cal Div Mines R27:337; R17:354; R15:822; B76:62
	Gallagher: see Black Mountain							
	Garringer: see Lee Yim							
	Hidden Treasure: see Monument King							
	Lankin: see Black Raven							
	Lavio Mountain: see Lee Yim							

## SAN BERNARDINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prop.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
11	Logan (Trans-Oceanic, Treasure)	E.T. Logan (Suckow Borax Mines Cons., lessee)		SW9N	6E	SB	C	Manganese oxide and calcite in fissures in andesite Active 1942 (1) Location approximate
	Manganese 1-10: see Lee Yim							
	Manganese Cliff: see Black Prince							
	Manganese King: see Black Prince, Monument King							
	McDowell: see Dawson							
12	Monument King (Manganese King, Hidden Treasure)	Fred M. Hall (power of attor- ney); (Bowen and Cady, lessees)	1 6	2N 2N	25E 26E	SB SB	B	Lenticular bodies of manganese oxide and hematite associated with jasper in limestone Active (1,2) Cal Div Mines R 27:338; R17:355 Jones, E.L., Jr. (19) 185, 190
13	Moulton (Red Cross)	C.E. Moulton (Wm. Bradbury, lessee; former- ly F.W. Hall)	6,7	2N	26E	SB	C?	Same type as Monument King Active (1,2)

## SAN BERNARDINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
14	New Deal (Old Hole, Owls Hole)	Manganese Mining Co. (lessee): (formerly E.R.K. Waite, Natural Resources, Inc.)	18	18N	3E	SB	A	Fissure deposit Active (1,2) Cal Div Mines R27:337; R17:355; R15:822; B105; 184; B107:181; B76:62 Min Res U.S. 1923:282; 1929:282; 1930:305; 1931:160
15	Northrup	Northrup	8	8N	3E	SB	D	Like Black Raven (2)
16	Orchard, Dunbar	Robert Orchard or Charles Dunbar	10	3N	26E	SB	D	Manganiferous conglomerate. Fissure deposit? (1)
17	Old Hole: see New Deal Owls Hole: see New Deal Owls Spring  Red Cross: see Moulton		18	18N	3E	SE	D	Bedded oxide deposit in Tertiary lake beds (1,2) Cal Div Mines R27:337; R17:355; R15:822; B105; 184; B107:181; B76:62 Min Res U.S. 1923:282; 1929:282; 1930:305; 1931:160

## SAN BERNARDINO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
18	Reinert	E.A. Reinert	5	8N	8E	SB	C	Fissures in brecciated rhyolite. Mined out (2)
19	Stewart	J.W. Stewart (Mineral Materials Co., lessee)	NW6	3N	25E	SB	C	Fissures in fanglomerate Active (1)
	Trans-Oceanic: see Logan							
20	Turner	M.C. Turner	9?	3N	3E	SB	D	(2)
21	Vivian	Al Vivian		3N	5E	SB	D	(2) Location approximate

## SAN DIEGO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B & M.		
1	Clark	W.S. Clark	7, 18	9S	2W	SB	D	Manganese oxide stains in aplite dike (2)
2	Del Monte			17S	8E	SB	D	Shear zone in granite (3)
3	Engineers Springs	C.C. Valle	22	18S	2E	SB	D	Manganese oxide in rhyolite (2)
4	Jacumba group	Dr. M.C. Harding	5, 6	18S	8E	SB	D	Manganese oxide stains in granite Cal Div Mines R35:30; R21:350; R20:374
5	Machado	Machado	6	9S	2W	SE	D	Manganese oxide stains in aplite and pegmatite (2)
6	Ramrod	V.W. Deaver		18S	8E	SB	D	(3)
7	Ruby	D.A. Ruby	16	18S	8E	SB	D	Spessartite and rhodonite in schist (2)
8	Sunrise	Calvin W. Garrison	10	13S	5E	SB	D	Fissure vein Cal Div Mines R35:30
9	Turner	J.O. Turner	31	14S	5E	SB	D	Manganese oxide in iron-stained quartzite (2)

SAN JOAQUIN COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S. c.	T.	R.	B. & M.		
1	Callahan		NW12	4S	4E	MD	D	Typical Francisoan deposit (1,2)
	Corral Hollow: see Ladd							
2	Crocker	M. I. Crocker	35	4S	4E	MD	D	Typical Francisoan deposit Cal Div Mines R21:192; B76:64
3	Cummings (Lone Tree, Section 13)	Winship Estate (Lone Tree Mining Company, lessee)	13	4S	4E	MD	A	Typical Francisoan deposit Active (1,2) Cal Div Mines R21:193; R14:622; R10:564; B76:67
	Doak: see Mahoney							
4	Fabian	Maack C. Lake	2	4S	4E	MD	A	Cal Div Mines B76:65 Typical Francisoan deposit (1)
5	Ladd (Corral Hollow)	Connelly Ranch (Maack C. Lake, lessee)	2, 11	4S	4E	MD	A	Typical Francisoan deposit. Largest producer in state (1,2) Cal Div Mines R21:191; R20:163; R18:690; R17:166; R14:620, 621; R13:507; R11:121; R10:564; B11:45; B76:64 Min Ind v23:514 Min Res U.S. 1890:131; 1917:683; 1926:145; 1927:181 McCluer, S.H. (15) 172; (15a) 258 Harder, E.C. (09) 271; (10) 160, 166, 271 Penrose, R.A.F., Jr. (91) 61, 479, 486 Vickery, F.P. (25) 608 Weeks, J.D. (95) 405

SAN JOAQUIN COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	E. & M.		
6	Lone Tree: see Cummings  Mahoney (Doak)	Winship Estate (A.W.V. Johnson, lessee)	11	4S	4E	MD	D	Typical Franciscan de- posit Active (1,2) Cal Div Mines R21:193; R14:622; R10:564; B76:67
7	Scott  Section 13: see Cummings	Charles Scott	34	4S	4E	MD	D	Typical Franciscan de- posit (1)

## SAN LUIS OBISPO COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sig.	T.	R.	B. & M.		
1	Barneberg	Staneuch Estate	NE 7	31S	12E	MD	C	Typical Franciscan deposit (1,2)
2	Black Mountain	Fred Williams Joe Sousa Walter Carpenter	34	26S	9E	MD	D	Typical Franciscan deposit (2)
3	Bluebird	Lewis Foundation Corporation	30	28S	12E	MD	C	Typical Franciscan deposit. Near greenstone (1,2)
4	Egenes			30S	14E	MD	D	Typical Franciscan deposit (3)
5	Evans	W. and J. Evans	3	25S	6E	MD	D	Typical Franciscan deposit Cal Div Mines R31:427; R21:523; B76:70
	Pollet Ranch; see Morro Bay							
6	Hearst Ranch Marmolejo Creek	Hearst Ranch	S 1	26S	7E	MD	D	Oxide in boulders of calcite (1) Cal Div Mines R31:427; R21:523; B76:70
7	Hearst Ranch Red Rock	Hearst Ranch	SE13	26S	7E	MD	C	Nodules from serpentine (1,2) Cal Div Mines R31:427; R21:523; B76:70



## SAN LUIS OBISPO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION			B. & M.	CLAS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.			
8	Hill		16	28S	9E	MD	D	Typical Franciscan deposit (3)
9	Hobson	W. L. Hobson		28S	11E	MD	D	Typical Franciscan deposit Cal Div Mines R15:690; B76:70
10	Isom	Dave Isom	23	31S	13E	MD	D	Typical Franciscan deposit (2)
11	Johe Ranch	A. T. Adams	SE35	30S	11E	MD	B	Typical Franciscan deposit. Mainly neotocite. Active (1,2) Cal Div Mines R31:427; R21:523; B76:71
12	Kester	Pedro Quintano		29S	10E	MD	D	Typical Franciscan deposit (2)
13	Lanscioni	L. Lanscioni	13	30S	11E	MD	D	Typical Franciscan deposit (2)
	Marmolejo Creek: see Hearst Ranch							
14	Marquart	J. F. Marquart	23	27S	9E	MD	D	Typical Franciscan deposit (2)

## SAN LUIS OBISPO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
15	Mayfield	Solon Mayfield	1	27S	9E	MD	D	Typical Franciscan deposit. Near greenstone (2)
16	Mello	D. Mello	SE 8	31S	13E	MD	D	Typical Franciscan deposit (1,2)
17	Morro Bay (Follet Ranch)	A.T. Adams	SE22	28S	9E	MD	D	Typical Franciscan deposit (1) Active?
18	Muscio	Dante Muscio		28S	10E	MD	C	Typical Franciscan deposit Cal Div Mines R 31:427; R21:523
19	O'Connor Ranch	O'Connor Ranch	NE19 SW20	30S	12E	MD	B	Typical Franciscan deposit (1,2)
20	Phelan	Phelan Land and Cattle Company	11	27S	8E	MD	D	Typical Franciscan deposit (2) Cal Div Mines R31:427; R21:523; R15:690; B76:71
21	Prefumo Canyon	Staneuch Estate	SE 6	31S	12E	MD	D	Typical Franciscan deposit (1,2) Cal Div Mines R12:330
	Quintano: see Vollmer							
	Red Rock: see Hearst Ranch							

## SAN LUIS OBISPO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
22	Riccoli	V. Riccoli	10	28S	9E	MD	D	Typical Franciscan deposit. Neotocite (2) Cal Div Mines R31:427; R21:524; B76:71
23	Serrano	Carlos Serrano	NE 2	31S	11E	MD	D	Typical Franciscan deposit (1) Cal Div Mines R31:427; R21:524
24	Staneuch (Staneusuch)	Staneuch Estate	6	31S	12E	MD	A	Typical Franciscan deposit. Hausmannite present (1,2) Cal Div Mines R31:427; R21:524; R15:690; B76:72 B36:336
25	Thompson	C.C. Thompson					C	Loc. 7X Ranch, Paso Robles (3) Typical Franciscan deposit Active
26	Tobacco Creek	Wm. Bodine	2	26S	8E	MD	D	Typical Franciscan deposit (2)
27	Vollmer (Quintano)	Ernest Vollmer	NE 6	29S	11E	MD	D	Typical Franciscan deposit. Near greenstone (1,2)
28	Welch	Mrs. Lyda Welch	SE34	30S	11E	MD	A	Typical Franciscan deposit. Hausmannite present (1,2) Cal Div Mines R31:427; R21:524; R12:330; R15:689; B76:73 Min Res U.S. 1917, pt. 1: 642

## SAN LUIS OBISPO COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sr.c.	T.	R.	B. & M.		
29	Young	Monte Young					D	Fairbanks, H.W. (04) Harder, E.C. (10) 164  Typical Franciscan de- posit (3) Active

SANTA BARBARA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
1	Byrne and O'Donnell	Byrne and O'Donnell	SW 8	7N	29W	SB	D	Franciscan deposit (2)
2	LaLaguna Rancho	La Laguna Ranch Company	NE33	8N	30W	SR	D	Stains on Franciscan basalt (2) Cal Div Mines R21:542; B76:74
3	Morey  O'Donnell: see Byrne and O'Donnell	Morey	SW18	7N	29W	SB	D	Float (2)

## SANTA CLARA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
1	Acme Lode  Aitken-Wolfe: see Winship	James Renfrew J.W. Bonsack Ralph Bolt	NW30	6S	5E	MD	D	Typical Franciscan deposit. Rhodochrosite near surface (1)
2	Ala Mountain	Merchant Estate	28	5S	4E	MD	C	Typical Franciscan deposit Cal Div Mines R26:14; R17:193; B76:75; B38:336
3	Alma: see Queen Bee No. 1  Antonia	Matt Keller	E32	6S	5E	MD	D	Typical Franciscan deposit. Recrystallized manganeseiferous chert (1)
4	Avery	George D. Avery					D	Loc. Livermore region Typical Franciscan deposit (3)
5	Billy Goat (Wasp, K.H.D.)	John Plattner	12	6S	4E	MD	C	Typical Franciscan deposit (3)
6	Black Bear	D.P. Doak	34	5S	4E	MD	D	Typical Franciscan deposit (2) Cal Div Mines R26:14; R17:193; B76:75; B38:336 Harder, E.C. (10) 160

## SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
7	Black Beauty: see Turner							
	Blackbird (Black Hawk)	M.E. Fisher	NE28	6S	5E	MD	C	Typical Franciscan deposit (1,2) Cal Div Mines R26:14; R17:193; B76:76
8	Black Eagle	Antonia Harris	SE28	6S	5E	MD	C	Typical Franciscan deposit (1) Active
	Black Hawk: see Blackbird							
9	Black Horse	Antonia Harris	NE32	6S	5E	MD	C	Typical Franciscan deposit (1) Active
	Black Wonder: see Jones							
10	Cedar Tree	Antonia Harris Matt Keller	33	6S	5E	MD	D	Typical Franciscan deposit (1)
	Camp Beisie: see Fable							
11	Cottonwood	Matt Keller	SW28	6S	5E	MD	C	Typical Franciscan deposit (1) Active
	Davenport	Winship Estate	27	5S	4E	MD	D	Typical Franciscan deposit (2) Cal Div Mines R26:15; R17:194; B76:77

## SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prop.	REMARKS AND REFERENCES
			Sic.	T.	R.	D. & M.		
13	Davenport and Smith	Winship Estate	27	5S	4E	MD	C	Typical Franciscan deposit (2) Cal Div Mines R26:15; R17:194; B76:77
14	de Forest		12	7S	4E	MD	D	Typical Franciscan deposit Cal Div Mines R13:507
	Dead Oak; see Keller - Dead Oak							
	Doak; see Winship							
15	Doak No. 2	D.P. Doak	22	5S	4E	MD	C	Typical Franciscan deposit Cal Div Mines R26:15; R17:194; B76:77; B38:337
16	Fable (Camp Bessie)	T.H. Green	NE34	5S	4E	MD	C	Typical Franciscan deposit (2) Cal Div Mines R26:15; R18:195; R17:195; R13: 507; R12:330; R11:374; B76:78; B38:337 Harder, E.C. (09) 271; (10) 160, 162
17	Frankel	Frankel		6S	2E	MD	D	Typical Franciscan deposit (3)



## SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B & M		
18	Great Expectations  Holbrook and McGuire; see Winship	E. P. Newhall	36	5S	4E	MD	C	Typical Franciscan deposit (2) Cal Div Mines R26:15; R17:195; B76:79
19	Jones (Black Wonder)	Western Manganese Company	NW27	6S	5E	MD	A	Typical Franciscan deposit. Contains high-grade carbonate (1,2) active Cal Div Mines R26:14; R17:193; B76:76 Min Ind v12:516 Harder, E.C. (10) 162
20	K. H. D.; see Billy Goat  Keller Bros.	.	13	6S	4E	MD	D	Typical Franciscan deposit (2) Cal Div Mines R26:15; R17:195; B76:79
21	Keller - Dead Oak	Barker Corp.	NE32	6S	5E	MD	A	Typical Franciscan deposit (1) Active
22	Kelley	A. M. Kelley		9S	3E	MD	D	Loc. approximate Typical Franciscan deposit (2)

## SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
23	Kelley	E. Kelley	NW12	6S	4E	MD	D	Typical Franciscan deposit (2)
24	Lopez	Alfred Lopez	19?	9S	3E	MD	D	Typical Franciscan deposit Cal Div Mines R26:14
25	Mammoth	H. H. Ballentine	13	6S	4E	MD	C	Typical Franciscan deposit (2) Cal Div Mines R26:15; R17:195; B76:78 Dolbear, S. H. (15) 175
26	Mateos Ranch	John D. Mateos	9	6S	2E	MD	C	Typical Franciscan deposit (2) Cal Div Mines R26:15; R17:195; B76:78
27	May Be	Antonia Harris	SE28	6S	5E	MD	D	Typical Franciscan deposit (1)
28	McCoy	C. L. McCoy					C	Loc. near San Jose Active (3)
29	McGuire, Holbrook and: see Winship McPherson	J. L. McPherson					C	Active (3)

## SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
30	Mexican	Western Man- ganese Company	27	6S	5E	MD	D	Typical Francisoan de- posit (1,2)
31	Miller	Caldwell and Al- brecht					B	Loc. near San Jose (3)
32	Morgan Hill	Morgan Hill Waterworks		9S	3E	MD	C	Loc. approximate Typical Francisoan de- posit (2)
33	Mount Hamilton	University of California		7S	3E	MD	D	Loc. approximate (3)
34	Murmac	In litigation	SW21	6S	5E	MD	B	Typical Francisoan de- posit (1)
35	Newsom	Archie Newsom	SE26	5S	4E	MD	C	Typical Francisoan de- posit (1) Active
	Noble lease: see Pennsylvania							
36	Pennsylvania (Noble lease)	M.M. Day	12	73	4E	MD	B	Typical Francisoan de- posit (2) Cal Div Mines R26:15; R17:196; B76:79 Harder, E.C. (09) 271; (10) 160
	Penitentia Creek: see San Jose							

SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROB.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
37	Pine Ridge	Alfred Jackson	31	8S	4E	MD	B	Typical Franciscan deposit (1) Active
38	Pulse	Jack Pulse	3W26	5S	4E	MD	D?	Typical Franciscan deposit (1)
39	Queen Bee No. 1 (Alma)	Barker Corp.	SW29	6S	5E	MD	C	Typical Franciscan deposit (1) Active
40	San Jose (Penitencia Creek)	City of San Jose	27	6S	2E	MD	B	Several mangiferous minerals described by A.F. Rogers (19) 443 Cal Div Mines R13:507; R12:330; R9:55
	Smith: see Davenport and Smith							
	Summit: see Turner							
41	Triple Jump	W.J. Schroeder	SW28	6S	5E	MD	D	Typical Franciscan deposit (1)
42	Turner (Black Beauty, Summit)		NE26	5S	4E	MD	C	Typical Franciscan deposit (2)

SANTA CLARA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
43	Wallace Ranch	Mrs. G.P. Wallace	8	6S	2E	MD	C	Typical Franciscan deposit Cal Div Mines R26:15; R17:196; B76:79
	Wasp: see Billy Goat							
44	Winegar	Winship Estate	19	5S	4E	MD	B	Typical Franciscan deposit (2) Active
45	Winship (Aitken-Wolfe, Doak, Holbrook and McGuire)	Winship Estate	27 35	5S	4E	MD	B	Typical Franciscan deposit (1,2) Active Cal Div Mines R26:15; R17:194, 196; B76:80
	Wolfe, Aitken--: see Winship							

## SHASTA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Arps	C.L. Wilson		33N	4W	MD	D	Min and Sci Press (15) Loc. approximate
2	Dunoon Creek	American Mangan- ese Mining and Smelting Co.		30N	8W	MD	D	Eng and Min Jour (17) Loc. approximate
3	Exposed Treasure Barite			SW36N	1W	MD	D	Cal Div Mines R35:l66; R22:l99
4	Goat Camp	G.E. Reimert W.O. Friend	SW36	29N	11W	MD	D	Rhodonite in chert in greenstone (1) Cal Div Mines R37:67
5	Nicol	Mrs. E.M. Nicol	SW22	29N	9W	MD	D	Franciscan manganese chert near greenstone (1) Cal Div Mines R35:l67 (?)
6	Nigger Hill	Glen Murphy (Kuppinger and Pinkham, les- ses)	14	30N	8W	MD	C	Some rhodonite (1) Active 1942
	Peterson: see Shasta Copper							
	Pit River Consolidated: see Shasta Copper							
7	Shasta Copper (Pit River Consolidated, Peterson)	Shasta Copper Co.	36 1	34N 33N	4W 4W	MD	A	Replacement deposit in volcanics (2) Cal Div Mines R35:l66; R22:l99; R14:807; B76:80
8	Victor	Victor Mining Co.		29N	10W	MD	D	Manganeseiferous chert and rhodonite? (2)

## SISKIYOU COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Allen	J.F. Lewis Robert Reynolds	8	44N	8W	MD	C	Rhodonite (1,2)
2	Baker	Baker Bros.		45N	9W	MD	D	Oxide stains (2)
3	Barham	W.W. Barham	9 or 16	44N	8W	MD	D	Rhodonite Cal Div Mines R31:333; R27:62; B76:81
4	Brown	Bert Brown	30	39N	10W	MD	D	Rhodonite (1)
5	Callahan		32	40N	7W	MD	D	Rhodonite. Abandoned gold prospect (1)
6	Chapparral Hill	J.F. Lewis Robert Reynolds	9	43N	9W	MD	C	Active. Oxide (from rhodonite?) (1)
7	Collier	B.K. Collier	8	44N	8W	MD	D	Stains (2)
8	Crawford	Cyrus Crawford	28	46N	12W	MD	D	Rhodonite and mangani- ferous chert (1)
9	Davis	Reeves Davis		17N	7E	H	D	Rhodonite Cal Div Mines B76:81
10	Dozier	M. Dozier	15	46N	6W	MD	D	Rhodonite Cal Div Mines R31:333; R27:62; B76:81
11	Etna District	Frank Bodecker		41N	9W	MD	D	Rhodonite (1)

SISKIYOU COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
12	Everill	Charles Everill	9	46N	11W	MD	D	Rhodonite (1)
13	Fort Jones	J.F. Lewis R.B. Reynolds	3	43N	9W	MD	C	Active. Oxide (from rhodonite?) (1)
14	High Light No. 1	H.A. Rivers Robert Alpheus	25	14N	4E	H	D	Manganiferous chert (1)
15	Huey	Vernon Huey	1	17N	6E	H	D	Rhodonite (1)
16	Kappler	Charles Kappler	29	42N	9W	MD	D	Rhodonite (2)
17	Kelley Lake	Kelley	NE33	18N	7E	H	D	Oxide stains (1)
18	Lewis	John J. Lewis	20	43N	9W	MD	D	Oxide (from rhodochro- site?) (1)
19	Lighthill	Geo. Lighthill	22	45N	10W	MD	D	Oxide stains (1)
20	Manganese 1,2,3,4	Pat Crow	1,12	15N	7E	H	D	Manganiferous chert (1)
21	Mayland (White Bear, Skillen and Means)	Mayland Mining Company	18,19	39N	11W	MD	C	Rhodonite (1) Active Cal Div Mines R31:333; R27:62; B76:82
	Means, Skillen and; see Mayland							



## SISKIYOU COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY Phon.	REMARKS AND REFERENCES
			S. C.	T.	R.	B. & M.		
22	National Defense	James Edwards Mrs. E. Cleaveland	16	40N	10W	MD	D	Rhodonite (1)
23	Oro Fino No. 1	J. F. Lewis Robert Reynolds	17	43N	9W	MD	D	Oxide (from rhodonite?) (1)
24	Oro Fino No. 2	J. F. Lewis Robert Reynolds	17	43N	9W	MD	D	Carbonate (1)
25	Pinery Hill	E. C. Roberts	24	43N	10W	MD	D	Rhodonite (1)
26	Rhodonite	W. M. Wood Fred Brann	2	17N	7E	H	D	Rhodonite (1)
27	Scott River	J. F. Lewis Robert Reynolds	3	43N	9W	MD	D	Landslide material (1)
28	Seiad Creek  Skillen and Means: see May- land	Cyrus Crawford	6	46N	11W	MD	D	Manganiferous chert (1)
29	Sylvester	Chas. Sylvester	20	16N	8E	H	D	Rhodonite (1)
30	Walton	M. A. Walton	W25	43N	10W	MD	D	Oxide (from rhodochro- site?) (1)
31	Wykoff	E. H. Wykoff	3 or 10	18N	6E	H	D	Rhodonite ? (1)

## SONOMA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	E. & M.		
1	Aho (Drum)	Al Aho	15,16	8N	12W	MD	B	Typical Francisoan deposit (1) Active Cal Div Mines R22:338; B113:145
2	Archambeau (Lucky Strike)	W. Archambeau	24	11N	9W	MD	D	Typical Francisoan deposit (2)
3	Baker Ranch  Big Bluff; see Warner	Mrs. Harry Baker	31	11N	8W	MD	D	Typical Francisoan deposit (1,2)
4	Boyer	S.R. Boyer (D.W. Shanks and A.W. Copps, former lessees)	31	10N	10W	MD	A	Typical Francisoan deposit (1,2) Mined out Cal Div Mines R22:338; R17:249; B76:82
5	Dillon and Seefeldt	Mrs. Dillon H. Seefeldt		9N	14W	MD	C	Typical Francisoan deposit. Oxide stains (3)
6	Dreamland  Drum: see Aho	J.H. Rowan	6	8N	8W	MD	C	Typical Francisoan deposit (2)
7	Foerohler	G.A. Foerohler	34	8N	7W	MD	D	Typical Francisoan deposit (2)

## SONOMA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
8	Foss	C.C. Foss	19	11N	8W	MD	D	Typical Franciscan deposit Cal Div Mines R22:338; R17:249
9	Hayden	J.E. Hayden	7	8N	12W	MD	D	Typical Franciscan deposit Cal Div Mines R22:338
10	Holst-Weeks  Lucky Strike: see Archambeau	Frank Weeks	1	7N	7W	MD	D	Typical Franciscan deposit. Neotoolite (2)
11	McDonald	Henry McDonald	9	10N	8W	MD	D	Typical Franciscan deposit. Disseminated carbonate (2)
12	O'Connell	P.L. Curtis	13	10N	11W	MD	D	Typical Franciscan deposit (1)
13	Pine Flat  Seefeldt: see Dillon and Seefeldt	W.J. McLean C.F. Clark	9,10	10N	8W	MD	D	Typical Franciscan deposit. Chert in greenstone (2) Cal Div Mines B76:82

## SONOMA COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
14	Sharp	Newton Sharp	7	8N	7W	MD	D	Chert in greenstone. Typical Franciscan de- posit (2)
15	Warner (Big Bluff)	Paul Warner	SW10	10N	8W	MD	D	Chert in greenstone. Typical Franciscan de- posit (2)
	Weeks: see Holst-Weeks							
16	Wheeler		20	10N	8W	MD	D	Typical Franciscan de- posit (2) Cal Div Mines B76:83
17	White-O-Ranch	J.L. McEachern	8	8N	9W	MD	D	Oxide stains (1)
18	Wright	George Wright	7	11N	10W	MD	D	Typical Franciscan de- posit (1)

## STANISLAUS COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			S.E.	T.	R.	B. & M.		
1	Black Bolt	James Renfrew J.W. Bonsack Ralph Bolt	NE21	6S	5E	MD	D	Typical Franciscan deposit (1)
2	Black Mike (Black Point, Black Rock)  Black Point: see Black Mike  Black Rock: see Black Mike	Harold Tripp	NW14	6S	5E	MD	D	Typical Franciscan deposit (1)
3	Brinkerhoffer (Brown)  Brown: see Brinkerhoffer	Runner and Brinkerhoffer	18	5S	6E	MD	C	Typical Franciscan deposit (2)
4	Buckeye (Wright)	Winship Estate (Verner Allen, lessee)	2,3	5S	5E	MD	A	Typical Franciscan deposit. Contains high-grade carbonate (1,2) Active Cal Div Mines R21:212; B103:184; B88:47; B76:85
5	Claim 14		15	6S	5E	MD	D	Typical Franciscan deposit (1)
6	Clear Creek (Cummings lease)	J.J. Cummings and son, former lessees	19	5S	6E	MD	B	Typical Franciscan deposit (2) Cal Div Mines B76:87
7	Coast Manganese	Coast Manganese Co., lessee	Appr. 11	5S	5E	MD	C	Typical Franciscan deposit (1) Active

STANISLAUS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
8	Crocker  Cummings lease: see Clear Creek	M. I. Crocker	33	5S	6E	MD	D	Typical Franciscan de- posit Cal Div Mines B76:83
9	Gerber	Wm. Crittenden, lessee	SE27	6S	5E	MD	B	Typical Franciscan de- posit (1) Active
10	Grayson		25	6S	5E	MD	D	Typical Franciscan de- posit Cal Div Mines R11:465
11	Grummett-Knox	Wm. Grummett (Rutherford, lessee)	6	5S	6E	MD	C	Typical Franciscan de- posit (1,2) Active Cal Div Mines B76:84
12	Grummett No. 2	A. Grummett	6	5S	6E	MD	D	Typical Franciscan de- posit (2)
13	Hamilton (Mitchell, Hospital Canyon)	J. P. Warren	15	5S	5E	MD	B	Typical Franciscan de- posit (3) Active
14	Hammond  Hospital Canyon: see Hamilton	W. J. Hammond	8	6S	6E	MD	D	Typical Franciscan de- posit (2) Manganiferous iron ore

## STANISLAUS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
	Ingram Canyon: see Tip Top							
15	Jake Smith	J.P. Warren	22?	5S	5E	MD	C	Typical Franciscan deposit (3) Active
	Knox: see Grummett-Knox							
16	Liberty	M.A. Wright? (Humphreys Gold Co., lessee)	36	4S	5E	MD	A	Typical Franciscan deposit (1,2) Active Cal Div Mines R21:213
17	Look Out	Mary Lou Thronson	10	6S	5E	MD	D	Typical Franciscan deposit (1)
18	Magnesia Camp	Mineral Products Company	8	6S	6E	MD	D	Typical Franciscan deposit (2)
19	Mary Lou No. 1	Mary Lou Thronson	E21	6S	5E	MD	D	Typical Franciscan deposit (1)
20	Mezzero	Grummett Ranch	SW 6	5S	6E	MD	C	Typical Franciscan deposit (1) Active
	Mitchell: see Hamilton							
21	Moran Bros.	Peter Moy (Humphreys Gold Co., lessee)	36	4S	5E	MD	B	Typical Franciscan deposit (1,2) Active

## STANISLAUS COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	E. & M.		
22	Park group  Seagrave: see Tip Top		SE21	6S	5E	MD	D	Typical Franciscan deposit (1)
23	Section 23	J.P. Warren	23	5S	5E	MD	B	Typical Franciscan deposit (1) Active
24	Sulphur Gulch	E.H. Henderson W.W. Breite Herman Ludwig Frank Mason	2	5S	5E	MD	D	Typical Franciscan deposit (1,2)
25	Summit						C	Typical Franciscan deposit (2)
26	Sunbeam	Winship Estate (W.H. Wilson, J.J. Donahue, J. McFarland, former lessees)	11, 13,14	5S	5E	MD	B	Typical Franciscan deposit (2) Cal Div Mines B76:87
27	Thompson Bros.	Winship Estate	25	5S	5E	MD	C	Typical Franciscan deposit (1) Cal Div Mines B76:87
28	Tip Top (Seagrave, Ingram Canyon)  Wright: see Buckeye	Winship Estate (M.A. Wright and S. Johnson, lessees)	1	5S	5E	MD	B	Typical Franciscan deposit (1,2) Active Cal Div Mines B76:84



## TEHAMA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Proc.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
	Anti-Hitler: see Manganese Peak Anti-Mussolina: see Manganese Peak							
1	Cavaleri	John Cavaleri (formerly Thurston)	NW14	24N	7W	MD	D	Franciscan chert (2) Cal Div Mines R15:262 (?)
2	Elva	C.S. Beuner	30	23N	7W	MD	D	Franciscan chert Cal Div Mines R24:214; R15:262; E76:87
3	Lockwood	Lett Lockwood	9	23N	7W	MD	D	Franciscan chert Cal Div Mines E76:88
4	Logan	E.P. Logan	17	23N	7W	MD	D	Bementite (2)
5	Manganese King	Horace Gregory Chas. Moffitt	NE 8	27N	9W	MD	D	Bementite (1)
6	Manganese Peak (Anti-Hitler, Anti-Mussolina)	W.H. Leland G.H. Bradbury	20	23N	7W	MD	D	Franciscan chert (1,2) Cal Div Mines R15:262; E76:88
7	Tehama	G. Allen J.A. Milham	1,2 11,12	26N	10W	MD	D	Oxide in schist (3)

## TRINITY COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			S. & C.	T.	R.	B. & M.		
1	American Manganese No. 1 and 2	George Maker (1) Gail Read (2)	SW23	3N	7E	H	D	Pre-Franciscan chert (1)
2	Apple Flat	Robert Hill Ann Anderson (Victory Mangan- ese Company, lessee)	N13	2S	7E	H	D	Franciscan (1)
3	Armstrong No. 1	Robert Hill H.J. Anderson	NE19	3S	8E	H	D	Franciscan carbonate and bementite (1)
4	Armstrong No. 2	Robert Hill H.J. Anderson (Victory Mangan- ese Co., les- see)	SW20	3S	8E	H	D	Franciscan carbonate and bementite (1)
5	Armstrong No. 3	Robert Hill Ann Anderson (Victory Man- ganesse Co., lessee)	SW20	3S	8E	H	D	Franciscan (1)
6	Arrowhead (Black Susan)	J.A. Hoelling Sarah Hoelling	SW30	1N	8E	H	D	Pre-Franciscan chert; rich in iron (1)
7	Bald Steer	A.G. Trinkle G.E. Purcell	17	25N	12W	MD	D	Pre-Franciscan chert (2) Cal Div Mines B76,44
	Bear: see Hart and Bear							

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
8	Bear Ridge	George A. Kniss Lee Murphy	SE25	1S	5E	H	D	Franciscan (1)
9	Bertha (Yolla Bolly)	J. Mosier et al.	SE32	27N	10W	MD	D	Franciscan carbonate and bementite (1)
10	Big Boy	Arthur Crossman	SW17	3S	6E	H	D	Franciscan (1)
11	Big Buck (Munson group No. 1)	Edwin Lowry	SE 4	1S	8E	H	D	Pre-Franciscan chert (1)
12	Big Horn No. 1	White Ranch (Rae F. Helmske, lessee)	SE 9	4S	6E	H	D	Franciscan (1)
13	Big Horn No. 2	White Ranch (Rae F. Helmske, lessee)	9	4S	6E	H	D	Franciscan (3)
14	Big Rock	Wm. Rowland E.V. Lehmann, Jr.	SW12	3N	6E	H	D	Pre-Franciscan chert (1)
	Billy Sunday: see Lucky Sunday							
15	Black Bird	J.N. Hutchens	N4	2S	7E	H	D	Franciscan (1)
16	Black Hawk	J.N. Hutchens	NW3	2S	7E	H	D	Franciscan (1)
17	Black Hawk	George Silvester	NW32	29N	11W	MD	D	Films on greenstone (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
18	Black Oak	A. Crossman T.K. Tyree	NW5	3S	6E	H	C	Franciscan (1) Active
19	Black Rock	Lawrence Leck- rone	SW12	3N	6E	H	D	Pre-Franciscan chert (1)
	Black Susan; see Arrowhead							
	Blue Bird; see Blue Jay							
20	Blue Jay (Blue Bird)	J.M. McKnight A.M. McKnight F.A. Stookel (James I. Scott Co., lessee)	NW17	26N	12W	MD	A	Franciscan carbonate, oxide, and hausmannite. Active (1) Cal Div Mines R37;67
21	Blue Lizard	White Ranch (Rae F. Helmke, lessee)	9	4S	6E	H	D	Franciscan (3)
22	Bonanza	J.M. McKnight F.A. Stookel	SW3	27N	12W	MD	D	Franciscan (1)
	Bramblett; see Murphy-Bram- lett							
23	Briggs	Dean Briggs	W10	3S	6E	H	D	Franciscan (1)
24	Broken Hammer	White Ranch (Rae F. Helmke, lessee)	10	4S	6E	H	D	Franciscan (3)
25	Brown Dog	J.N. Hutchens	SW34	1S	7E	H	D	Franciscan (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
26	Bucking Camp No. 1	Rohrbough Ranch	NW32	3S	6E	H	D	Franciscan (1)
27	Bucking Camp No. 2	Rohrbough Ranch	NE32	3S	6E	H	D	Franciscan (1)
28	Carr	W.B. Carr	SW30	31N	12W	MD	D	Pre-Franciscan chert (1)
29	Carrie	T.M. Porter	SW30	31N	12W	MD	D	Pre-Franciscan chert (1)
	Caudwell: see Spider							
30	Cedar Springs	J.W. Patton	NW31	1N	8E	H	D	Pre-Franciscan chert (1)
31	Claim 23		NW29?	1N	8E	H	D	Pre-Franciscan chert (1)
32	Coldwater No. 1	White Ranch (Rae F. Helmke, lessee)	NE5	4S	6E	H	C	Franciscan (1) Active
33	Coldwater No. 2	White Ranch (Rae F. Helmke, lessee)	NE5	4S	6E	H	C	Franciscan (1) Active
34	Corner No. 1 and No. 2	White Ranch (Rae F. Helmke, lessee)	5	4S	6E	H	D	Franciscan (3)
35	Coyote	George A. Kniss Lee Murphy	SW13	3S	6E	H	D	Franciscan (1)
36	Dahrman (Yolla Bolly)	J. Mosier et al.	SW33	27N	10W	MD	D	Franciscan carbonate and bementite (1)

## TRINITY COUNTY - cont.

NO	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
37	Double A	Robert Hill Ann Anderson (Victory Mangan- ese Co., lessee)	16	3S	8E	H	D	Franciscan. Contains carbonate and hausmann- ite (1)
38	Dry Lake	Clarence Patton (Vance and Barnes, les- sees)	SW13	30N	12W	MD	D	Pre-Franciscan chert; high in iron (1)
39	Dubakella King: see Skaggs Emma (Yolla Bolly)	J. Mosier et al.	SE32	27N	10W	MD	D	Franciscan carbonate and bementite (1)
40	Foss	Fred Foss C. Skaggs (Noble Electric Steel Company, former lessee)	16	29N	11W	MD	D	Oxide (derived from rhodonite?) (2) Cal Div Mines R37168
41	Four Point	Robert Sihlis	NW29	1N	8E	H	D	Pre-Franciscan chert (1)
42	Gool No. 2	C.M. Patton J.W. Patton	SW30	1N	8E	H	D	Pre-Franciscan chert (1)
43	Gool No. 3	Ralph Patton	SW30	1N	8E	H	D	Pre-Franciscan chert (1)
44	Halc Creek	S. Hutchins H.T. Moore (Warren Doty and Sid Killings- worth, lessees)	NW23	1S	6E	H	D	Franciscan carbonate, bementite, and inosite (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
45	Hart and Bear	J.M. McKnight et al.	NE3	26N	12W	MD	D	Franciscan (1)
46	High Lead	W.R. Shields	13	29N	12W	MD	D	Pre-Franciscan chert (1)
47	Jaybird	H.W. Hoelling	NW33	1N	8E	H	D	Pre-Franciscan chert (1)
48	Jewett	Ray Latham	NW32	29N	11W	MD	D	Pre-Franciscan chert (1)
	Johnson: see Lucky Bill							
49	Kekawaka	White Ranch (Rae P. Helmke, lessee)	NE14	4S	6E	H	D	Franciscan (1)
	Kindred, McKnight and: see White							
50	Lampley	Jesse Lampley	NE33	3S	6E	H	D	Franciscan (1)
51	Last Chance	Sarah Hoelling	NW32	1N	8E	H	D	Pre-Franciscan chert (1)
52	Last Hope	M.M. White	NE27	31N	11W	MD	D	Pre-Franciscan chert (1)
53	Little Deer No. 1	A.G. Trinkle G.E. Purcell	17	25N	12W	MD	D	Pre-Franciscan chert (2) Cal Div Mines B76:44

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			SEC.	T.	R.	B. & M.		
54	Little Deer No. 2	A.C. Trinkle G.E. Purcell	17	25N	12W	MD	D	Pre-Francoisan chert (2) Cal Div Mines B76:44
55	Lookout	George A. Kniss Lee Murphy	NE34	2S	6E	H	D	Francoisan (1)
56	Lost Mine	F.A. Stockel J.M. McKnight	SW16	3S	8E	H	D	Francoisan (1)
57	Louella	B.E. McFadden	SW30	31N	12W	MD	D	Pre-Francoisan chert (1)
58	Lucky Bill (Old Bill, Johnson)	T.E. Reynolds	9	28N	11W	MD	D	Rhodonite, bementite, and rhodochrosite (1,2) Cal Div Mines R22:63; R37:68; B76:90
59	Lucky Star	Robert Shields	SW6	29N	12W	MD	D	Pre-Francoisan chert (1)
60	Lucky Sunday (Billy Sunday)	J.M. McKnight F.A. Stockel (James I. Soott Co., lessee)	NW32	27N	12W	MD	D	Francoisan oarbonate (1)
61	Manganese Queen	Charles Crews (A. Granzotto Construction Co. lessee; formerly Vance and Bar- nes)	SE26	30N	12W	MD	B	Rhodonite, bementite, and rhodochrosite (1) Active
62	Maple Springs: see White Mary Luc	Agnes Wilburn	SW32	2S	8E	H	D	Francoisan (1)



## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			S.E.C.	T.	R.	B & M		
	McKnight and Kindred: see White							
63	Montgomery	White Ranch (Rae F. Helmke, lessee)	SW15	4S	6E	H	D	Francisoan (1)
64	Moody (Neaphus Peak)	Moody Ranch	NE7	4S	6E	H	C	Francisoan (1.2) Cal Div Mines R22:63; B76:90
	Munson Group No. 1: see Big Buck							
65	Munson Group No. 2	W.H. Munson	N4	1S	8E	H	D	Francisoan (1)
66	Murphy-Brammlett	Chas. Murphy Wm. Brammlett	7	28N	11W	MD	D	Oxide (derived from rhodonite?) (2)
	Neaphus Peak: see Moody							
67	North Fork	F.A. Stockel	SE21	27N	12W	MD	D	Pre-Francisoan chert (1)
	Old Bill: see Lucky Bill							
68	Plummer Peak		SW33	31N	12W	MD	D	Pre-Francisoan chert (1)
69	Rainy Day	J.M. McKnight F.A. Stockel M.C. Fowler (James I. Soott Co., lessee)	SW8	26N	12W	MD	C	Franciscan carbonate (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
70	Rattlesnake	L.C. Taylor Hettie Taylor	NW5	29N	12W	MD	D	Pre-Franciscan chert (1)
71	Red Cliff	W.J. Azbill	36	5S	8E	H	D	Pre-Franciscan chert (2) Cal Div Mines R22:63; B76:90
72	Reichert	J.F. Reichert	S22	31N	11W	MD	D	Pre-Franciscan chert (1)
73	Rice Road No. 1	Hobrough Ranch (Rae F. Helmke, lessee)	31	3S	6E	H	D	Franciscan (3)
74	Salt Creek	R.S. Hinch Homer Hinch	SW18	30N	11W	MD	D	Pre-Franciscan chert (1)
75	Salt Creek No. 2	R.S. Hinch	NW19	30N	11W	MD	D	Pre-Franciscan chert (1)
76	Salt Creek No. 3	R.S. Hinch	NW19	30N	11W	MD	D	Pre-Franciscan chert (1)
77	Schoolhouse No. 1	White Ranch (Rae F. Helmke, lessee)	NE9	4S	6E	H	D	Franciscan (1)
78	Shell View No. 1	White Ranch (Rae F. Helmke, lessee)	NW16	4S	6E	H	D	Franciscan (1)
79	Shell View No. 2	White Ranch (Rae F. Helmke and A. Cross- man, lessees)	NW16	4S	6E	H	C	Franciscan; contains rhodonite and rhodo- chrosite (1) Active

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	R. & M.		
80	Shell View No. 3	White Ranch (Rae F. Helmke, lessee)	17	4S	6E	H	D	Franciscan (3)
81	Skaggs (Wildwood, Dubakella King)	Carol Skaggs	24	29N	11W	MD	D	Pre-Franciscan chert (3)
82	Snowcamp	Clarence A. and Willis Patton	SE27	2N	7E	H	D	Pre-Franciscan chert (1)
83	Source No. 1	White Ranch (Rae F. Helmke, lessee)	SW5	4S	6E	H	D	Franciscan (1)
84	Spider (Caudwell)	W.O. Friend	NE20	28N	11W	MD	D	Rhodonite, bementite, and rhodochrosite (1) Cal Div Mines R37:68; R22:63; B76:89
85	Stockton	Warren Stockton	SW9	3S	6E	H	D	Franciscan (1)
86	Summit No. 1	White Ranch (Rae F. Helmke, lessee)	SE6	4S	6E	H	D	Franciscan (1)
87	Sylvester-Wilson	Joseph Sylvester James Wilson	34	29N	11W	MD	D	Oxide (derived from rhodonite?) (2) Cal Div Mines R22:63; B76:90
88	Tan Oak No. 1	Rohrbough Ranch	SW32	3S	6E	H	D	Franciscan (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
89	The Cliff	S.L. Blake Hettie Taylor	NE22	31N	11W	MD	D	Pre-Francoiscan chert (1)
90	The Manganese	T.J. Montgomery	SE4	1S	8E	H	D	Pre-Francoiscan chert (1)
91	Twisted Oak No. 1	White Ranch (Rae F. Helmke, lessee)	SW9	4S	6E	R	D	Francoiscan (1)
92	Two Sugar Pines	G.L. Crews Hettie Taylor (Vance and Bar- nes, lessees)	SE20	31N	12W	MD	D	Pre-Francoiscan chert (1)
93	Vance group	Wm. G. Vance	25,26 35,36	30N	12W	MD	D	In serpentine; no man- ganese ore (1)
94	Wagon No. 1	Rohrbough Ranch (Rae F. Helmke, lessee)	SE6	4S	6E	H	D	Francoiscan (1)
95	Wagon No. 2	Rohrbough Ranch (Rae F. Helmke, lessee)	2	4S	6E	H	D	Francoiscan (3)
96	Ware No. 1	Philip Ware	SE18	3S	6E	H	D	Francoiscan (1)
97	Ware No. 2	Philip Ware	SE 8	3S	6E	H	D	Francoiscan (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prob.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
98	Weed	Frank Weed	34	29N	11W	MD	D	Pre-Franciscan chert (2)
99	White (Maple Springs, McKnight and Kindred)	Wm. P. White Estate (former- ly Kindred and Asbill)	NW8	4S	6E	H	C	Franciscan (1,2) Cal Div Mines R22:63; B76:91
100	Whiteman	J. W. Patton	SW30	1N	8E	R	D	Pre-Franciscan chert (1)
101	White Oak	Robert Hill Ann Anderson (Victory Man- ganese Co., lessee)	NE13	2S	8E	H	D	Franciscan (1)
	Wildwood: see Skaggs							
	Wilson: see Sylvester-Wilson							
102	Wood	Rohrbough Ranch (E. P. Wood, lessee)	SE31	3S	6E	H	D	Franciscan (1)
103	Woods	Mrs. Wood	NE27	31N	11W	MD	D	Pre-Franciscan chert (1)

## TRINITY COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
104	Wool Mountain No. 1	Rohrbough Ranch (Rae F. Helmke, lessee)	NE31	3S	6E	H	D	Francoiscan (1)
105	Wool Mountain No. 2	Rohrbough Ranch (Rae F. Helmke, lessee)	NE31	3S	6E	H	D	Francoiscan (1)
	Yolla Bolly: see Bertha, Emma, Dahrman							

## TULARE COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS BY PROD.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
1	Barbour	Ben K. Stroud	33	19S	29E	MD	D	Manganese oxide in quartz vein in granite (1) Cal Div Mines R15:940; B76:91
2	Cole	R.D. Cole	32	19S	27E	MD	D	Manganiferous iron ore in chert Cal Div Mines R15:941; B76:91
3	Dry Creek		23?	15S	27E	MD	D	Cal Div Mines R26:454; R18:535
4	Gill Ranch	Z.E. Pope		20S	28E	MD	D	Rhodonite (3)
5	O'Kelly	L.W. O'Kelly		21S	29E	MD	D	Manganese oxide stains in metamorphic rock (3)

## TUOLUMNE COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By Prod.	REMARKS AND REFERENCES
			Sec.	T.	R.	B. & M.		
	Bulldog: see Hughes							
	Experimental: see Schoettgen							
1	Flaming Arrow	Nathan Williams	21	3N	15E	MD	D	Rhodonite (3)
2	Hog Mountain	Chas. Sutton	5	1S	15E	MD	D	Rhodonite (2) Cal Div Mines B76:91
3	Hughes (Bulldog)	T.M. Hughes or F.E. Cummings	17	2S	15E	MD	C	Mainly rhodonite, but may contain rhodo- chrosite (1,2)
4	Jasper	Ed M. Jasper	NE23 NW24	1S	13E	MD	D	Manganese oxide stains in quartzite (1)
5	Madrid	John Madrid	25?	2N	14E	MD	D	Rhodonite Cal Div Mines R5:106; B76:91 Harder, E.C. (10) 165
6	Pedro (Stonewall)	A.L. Pedro	25	2N	14E	MD	D	Rhodonite (1,2) Cal Div Mines R5:106 Turner and Ransome (97)
7	Schoettgen (Experimental)	Frank Schoettgen	1	2N	14E	MD	D	Superficial residue in limestone (1)

TUOLUMNE COUNTY - cont.

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sfc.	T.	R.	B. & M.		
8	Stonewall: see Pedro West	J.H. West	6	1N	16E	MD	D	Rhodonite (2)
		C.R. Windeler Frank E. Knight L.R. Knutte	29	3N	15E	MD	D	Spessartite (1)
		Ed Evans Geo. McGirk (Tom Neally, lessee)	S33	2S	16E	MD	C	Partially oxidized spessartite and rhodonite Active (1)

YUBA COUNTY

NO.	NAME OF CLAIM	NAME OF OWNER	LOCATION				CLASS By PROD.	REMARKS AND REFERENCES
			Sfc.	T.	R.	B. & M.		
1	Bean (Kingbird)	R.J. Bean et al.	36	20N	7E	MD	D	Placer gold property; blocks of oxide, derived from rhodonite? (1)
2	Clemens	Fred Clemens	29	19N	7E	MD	D	Rhodonite (2)



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# GENESIS OF THE MANGANESE DEPOSITS OF THE COAST RANGES OF CALIFORNIA

By N. L. TALIAFERRO \* and F. S. HUDSON \*\*

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## ABSTRACT

The manganese deposits of the Coast Ranges always occur in the Franciscan-Knoxville group of late Jurassic age. Except in a few rare cases they always are interbedded with radiolarian cherts, either red or green. Furthermore, they are nearly always directly associated with the more massive cherts that interrupt the rhythmic bedding of the thin-bedded cherts and shales.

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The lenses of manganese ore have the same shape and mode of occurrence as the ordinary chert lenses and this similarity even extends to their internal structures. The ore lenses vary from less than an inch in thickness to 25 feet, averaging less than 4 feet. Usually they are not over 40 or 50 feet in length, but may be as much as 600 feet.

From a study of the little-altered deposits the manganese appears to have been present originally as spherulitic or finely divided manganese carbonate and as a manganese opal of variable formula. These two substances may occur as relatively pure deposits or mixed in varying proportions; most orebodies are of the latter type.

Alteration of the original deposits by various types of metamorphism and hydrothermal action has produced a great variety of minerals. Ordinary alteration produces granular manganese carbonate and various hydrous manganese silicates. Hydrothermal alteration sometimes produces ores made up of hausmannite, braunite, rhodochrosite, and various hydrous manganese silicates.

The original ores and their alteration products are readily oxidized to the black manganese oxides at the surface and along joints and fracture planes. Oxidation may range from a mere film to a depth of many feet.

The original manganese ores are regarded as syngenetic deposits laid down contemporaneously with the cherts with which they are interbedded. So constant is the association of chert and manganese and iron deposits in the Franciscan-Knoxville group of the Coast Ranges that silica, manganese, and iron are believed to have a common source. The close and practically constant association of the cherts with contemporaneous basic lavas indicates that the volcanics were the chief source of silica, manganese, and iron.

## INTRODUCTION

The object of this paper is to present all pertinent field data on the mode of occurrence and association of the manganese deposits of the Coast Ranges of California and the conclusions as to genesis that may be drawn from them. Only that phase of the mineralogy of the deposits that bears on the genesis will be presented. Fuller details regarding the large number of secondary minerals that are often present will be given in a future paper. The chief discussion will be devoted to the original ores below the oxidized zone; conversion of the original material into black manganese oxides will only be briefly treated. As a background for the discussion of the mode of occurrence of the primary ores it will be necessary to give a brief account of the rocks in which they occur. Previous theories regarding the origin of the ores will be presented and reviewed.

The importance and extent of the manganese industry in the Coast Ranges will not be touched upon as this is adequately covered elsewhere in this bulletin. It is sufficient to state that there are but few mines that have produced over 1000 tons of relatively high-grade ore. However, the aggregate tonnage of many small mines and prospects has been considerable and also there exists a large, untouched tonnage of low-grade, high-silica ores that may, possibly, assume importance in the future. To date no satisfactory commercial method of extracting the manganese from these low-grade ores has been developed. Because of the nature of the

ores any process for the extraction of the manganese would have to be based on chemical, rather than mechanical processes.

The field and laboratory work on which this paper is based was done chiefly in the years 1917 to 1919; during this period all of the then known mines, prospects, and reported occurrences of manganese in the Coast Ranges and Sierra Nevada were visited. Some of the more important deposits were visited several times. Since then the senior author has examined a number of the more recently discovered deposits and has carried on work in the laboratory.

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#### THE COAST RANGES OF CALIFORNIA

The precise limits of the Coast Ranges, in common with many similar general geographic terms, are somewhat difficult to establish. This is particularly true on the north and south where the commonly accepted boundaries are rather indefinite and not wholly logical. The Coast Ranges, for the purpose of the present paper, are defined as that group of ranges, often with intervening valleys of considerable length, extending from Santa Barbara County northward to the Klamath Mountains and from the Pacific Ocean eastward to the great central valley of California. On the south they merge into the Transverse Ranges that trend approximately eastward through southern Santa Barbara County. On the north their generally accepted boundary against the Klamath Mountains is geologic rather than strictly geographic or physiographic. Their termination in that direction is, in part, a northwest trending thrust fault that lies near the crest of South Fork Mountain and brings ancient crystalline schists (Salmon and Abrams schists) and metamorphosed Paleozoic rocks over Franciscan and Cretaceous. Where definitely known this great fault dips  $40^{\circ}$  to  $65^{\circ}$  NE. It appears to steepen northward as it has rather a high dip where it intersects the coast line between Big Lagoon and Orick, about 25 miles south of the mouth of Klamath River. Nothing is known regarding its southeastward continuation beyond the southeast end of South Fork Mountain, where it dips  $40^{\circ}$  to  $45^{\circ}$  NE., as it there enters the geologically unexplored and very inaccessible region in the southeastern corner of Trinity County. The

approximate limits of the Coast Ranges, as thus defined, are shown in figure 1.

It is beyond the scope of the present paper to discuss the complex physiography, stratigraphy, and structure of this large and very diverse area, which has a maximum length of 550 miles, a width of over 70 miles, and occupies approximately 25 percent of the total area of the State. The history of the Coast Ranges south of San Francisco Bay is far better known than that to the north, as the southern part has been almost completely mapped topographically and geologically. Geologic work in the northern Coast Ranges has been handicapped by three factors, namely, the rugged and inaccessible nature of much of the region, a lack of suitable maps, and a greater average rainfall, resulting in greater chemical weathering and the formation of a heavy soil mantle that obscures the underlying rocks in many areas.

The general geology of the Coast Ranges south of San Francisco Bay has been sketched by the senior author<sup>1</sup> and a more comprehensive account of this area, together with the known facts regarding the northern Coast Ranges, will be presented in the future. For the purpose of the present paper it is sufficient to state that, with the exception of certain relatively isolated areas of crystalline schists and plutonic intrusives of early Paleozoic or pre-Cambrian age, the Coast Ranges are made up of very late Jurassic, Cretaceous, Tertiary, and Quaternary sediments, volcanics, and shallow intrusives. The only rocks of importance in connection with the occurrence of manganese, are those of late Jurassic age; a discussion of these rocks and a brief account of the diastrophic history, also of importance in an understanding of the manganese deposits, will be given in a later section.

Those unfamiliar with the Coast Ranges commonly regard them as of comparatively low relief, a concept that is far from the truth as they contain some of the most rugged, mountainous areas of the State. They never attain elevations comparable with those in the southern Sierras but there are many peaks over 6000 feet in elevation and some more than 7000 feet. Except where river valleys or structural depressions intersect the coast line the mountains rise abruptly and precipitously from the Pacific Ocean. The Santa Lucia Range, that part of the Coast Ranges between Monterey and San Luis Obispo, presents an almost unbroken precipitous front along the coast, rising to elevations of 2500 feet and more within a mile of the coast line and, in places, to more than 5000 feet within 3 miles of the ocean. The eastern side, bordering the Great Valley, is flanked by Cretaceous and Tertiary sediments and the westward increase in elevation from the valley floor is rather gradual. However, there is no gradual increase from the Great Valley to a general crest, followed by a descent to the ocean, as the Coast Ranges are made up of a number of independent ranges separated by valleys. In general, the individual ranges and valleys are slightly oblique to the coast and both are truncated at a slight angle. South of San Francisco Bay the more important ranges are: Santa Cruz Mountains which lie between the coast and the southern San Francisco Bay—Santa Clara Valley depression; Santa Lucia Range lying between the ocean and the Salinas Valley; the Gabilan Mountains and Gabilan Mesa, actually a southeastward continuation of the Santa

<sup>1</sup> Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of California; California Div. Mines Bull. 118, pp. 119-162, 1943.

Cruz Mountains, lying between the Salinas Valley and the long, more or less continuous depression running southward from San Francisco Bay through the Santa Clara Valley and up the San Benito River. Between this depression and the San Joaquin Valley lies the Diablo Range, which actually is, itself, compound and susceptible of division into several independent ranges. The northern Coast Ranges are more complex and less susceptible of division. These ranges and valleys are shown in figure 1, a relief map of California.

## THE FRANCISCAN-KNOXVILLE GROUP

### General Statement

All of the manganese deposits of the Coast Ranges are found in the Franciscan-Knoxville group of late Jurassic age. Not only are they restricted to this group but to a particular rock type, the radiolarian cherts. Since the Franciscan-Knoxville group has been described by the senior author <sup>2</sup> the only rocks making up this heterogeneous assemblage that will be described in any detail are the radiolarian cherts.

As has been shown by Taliaferro, there is no unconformity between the Franciscan and Knoxville, as these units usually have been defined; and lithologic types formerly considered characteristic of the Franciscan are found, in several places, associated with sediments having a Knoxville lithology and containing fossils considered as characteristic of the Knoxville. Conditions favoring the deposition of radiolarian cherts persisted practically to the close of the Jurassic in some areas while in others dark "Knoxville" shales were being deposited at the same time. For this, and other reasons, it has seemed desirable to call this thick and closely related series of diverse rock types the Franciscan-Knoxville group. However, since the manganese deposits occur in rocks long considered as characteristic of the "Franciscan," as usually defined, this custom will be followed in the present paper. Where the term Franciscan only is used the rocks should be considered as belonging to the Franciscan-Knoxville group, as defined by the senior author.<sup>3</sup>

### Distribution

The Franciscan is widely distributed in the Coast Ranges and also in the Klamath Mountains of northern California and southwestern Oregon. South of San Francisco Bay the Franciscan is exposed at the surface over an area of at least 2500 square miles and north of the Bay over an area estimated to be approximately 9600 square miles. The total area over which the Franciscan-Knoxville group is exposed, in both the Coast Ranges and the Klamath Mountains is approximately 14,000 square miles.

It may be stated with reasonable certainty that between San Francisco Bay and Santa Barbara the Franciscan-Knoxville group either is exposed at the surface or underlies the surface over an area of over 12,000 square miles. Between San Francisco Bay and the northern border of the State this group is either exposed or underlies the surface over an area of at least 18,000 square miles. Thus this group underlies an area

<sup>2</sup> Taliaferro, N. L., Franciscan-Knoxville problem: *Am. Assoc. Petroleum Geologists Bull.*, vol. 27, pp. 109-219, 1943.

<sup>3</sup> *Idem.*

of at least 30,000 square miles in western California, approximately one-fifth of the total area of the State. This is only a part of the original extent of the group, as the geosyncline in which it was deposited continued northward into Oregon and to the west of the present coast line.

#### Age of the Franciscan-Knoxville Group

The age and relations of the Franciscan and Knoxville have been one of the most discussed and perplexing problems of Coast Range geology. Unfortunately the Franciscan has been correlated with so many wholly unrelated formations in the Sierra Nevada, Oregon, and southern California, that the problem has been greatly complicated. All of the stratigraphic and faunal evidence has been reviewed by the senior author<sup>4</sup> and the conclusion reached that the Franciscan and Knoxville are not separated by an unconformity, but constitute a group occupying a known and limited part of geologic time and of considerable stratigraphic value; this group is assigned to the Tithonian, the last stage of the Jurassic and is regarded as later than the Mariposa slates of the Sierra Nevada. The evidence on which these conclusions are based are presented in the publications cited.

#### Lithology

The Franciscan-Knoxville sequence is a rather heterogeneous assemblage of rock types, consisting of arkosic sandstones, clay-shales, radiolarian cherts, limestones, conglomerates, and contemporaneous volcanics in the form of flows, tuffs, breccias, and agglomerates. These were intruded by basic and ultrabasic rocks resulting in the occasional development of pneumatolytic schists along the contacts. Although made up of many diverse rock types there is a comparatively orderly sequence in their appearance.

The senior author has divided the Franciscan-Knoxville sequence into four stages<sup>5</sup> that merge into each other. There are many local irregularities and the four stages cannot be traced continuously throughout the extent of these beds because of many variations in the time of beginning and ending of volcanism. However, it is believed that this division as presented below, with all its imperfections and generalizations, will serve a useful purpose and will aid in clarifying many obscure relations.

#### First Stage, Lower Franciscan

Arkosic sandstones, representing the rapid, chiefly mechanical degradation of a recently uplifted, rugged land mass on the west, were deposited in a sinking basin between the western land mass and the recently uplifted, ancestral Sierra Nevada on the east. Volcanic outbursts were not common during this stage and few chemical sediments were formed.

<sup>4</sup> Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of California: California Div. Mines Bull. 118, pp. 123-127, 1943.

Taliaferro, N. L., Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. America Bull., vol. 53, pp. 71-112, 1942.

Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 109-219, 1943.

<sup>5</sup> Taliaferro, N. L., Geologic history and structure of the central Coast Ranges of California: California Div. Mines Bull. 118, pp. 119-162, 1943.

Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 109-219, 1943.

### Second Stage, Upper Franciscan

Widespread volcanism began during this stage. Deposition of arkosic sandstones continued but shales became increasingly abundant. Maximum development of volcanism and radiolarian cherts occurred during this stage; foraminiferal limestones were deposited here and there. The beginning of the intrusive phase of basic and ultrabasic rocks, and the contemporaneous development of pneumatolytic contact rocks (glaucophane and actinolite schists) took place at this time.

### Third Stage, Upper Franciscan and Lower Knoxville

The deposition of coarse and fine clastics, with shales becoming more abundant, continued; there was a marked decline in volcanism and the deposition of radiolarian cherts, except in local areas. Over most of the basin of deposition waning volcanism was marked by explosive activity rather than numerous flows. Intrusion of basic and ultrabasic rocks, and the formation of contact schists, continued. This stage is, as a rule, thinner than any of the others. However, it may overlap and even continue through the fourth stage in local areas. A moderately abundant Knoxville fauna is present in a few localities.

### Fourth Stage, Knoxville

Over most of the Coast Ranges this stage is characterized by fine clastics, such as silts, sandy shales, and clayey sandstones; pebble conglomerates are occasionally present. Little volcanism or chert deposition occurred in northern California, but both continued throughout this stage in local areas. Intrusion of basic and ultrabasic rocks continued practically throughout this stage but pneumatolytic contact schists were only rarely developed. An abundant Knoxville fauna is found in this stage, even in those areas in which volcanism still persisted.

Although there were many local variations and these stages can not be used as definite cartographic units, except in local areas, it is believed that they give a comprehensive picture of the usual sequence of events in the Coast Ranges of California during the closing stage of the Jurassic (Tithonian).

During these four stages a great but imperfectly known thickness of sediments and volcanics accumulated. The thickest continuous sections that can be measured are rarely over 10,000 feet but as neither the base nor the top is exposed, this is but a part of the original thickness. It is believed that the total thickness was probably in excess of 30,000 feet.

The great majority of the manganese deposits associated with the radiolarian cherts of the Franciscan-Knoxville group formed in the second stage, coinciding with maximum volcanism.

### Alteration of the Franciscan

The Franciscan sediments and volcanics nearly always stand at high angles and not uncommonly are overturned. Although they have experienced a number of periods of folding and faulting they are not greatly metamorphosed except locally, on the contacts of basic and ultrabasic intrusives. They were slightly folded and faulted and exposed to erosion in places by the Diablan orogeny between the Jurassic and Lower Cretaceous, again between the Lower and Upper Cretaceous by the mid-



Cretaceous disturbance, and in the middle of the Upper Cretaceous. They were removed from rather a large area, the Gabilan Mesa, south of San Francisco Bay, as a result of faulting, folding, and uplift in the late Cretaceous and Eocene. The relatively minor disturbances during the Miocene and early Pliocene probably did not greatly alter them but they were intensely folded and faulted in the late Pliocene and again in the mid-Pleistocene.

In the course of their long and complex history not only have they been repeatedly disturbed but also, in many places, buried beneath thick prisms of later sediments, sometimes over 40,000 feet in thickness. However, in spite of the folding and local deep burial they have not been altered by pure dynamic metamorphism to any great extent. The shales, locally, are somewhat slaty, especially where they have been deeply buried and the sandstones have been slightly sheared, often resulting in a recrystallization of the fine interstitial material. However, there are large areas in which the sediments show no indications of either dynamic or static metamorphism.

Because of a number of complex factors there appears to be a general belief that the Franciscan has been considerably metamorphosed. This belief is largely due to three almost completely unrelated phenomena; these will be briefly outlined. In the first place the Franciscan is a heterogenous assemblage of beds of greatly varying competency and these have been intruded by both late Jurassic and Tertiary igneous rocks. As a result of the various periods of folding to which the Franciscan has been subjected the beds have been crushed against the more rigid intrusives and contemporaneous volcanics and often are greatly crushed and sheared. As a result the beds often have a very disordered appearance with little or no regularity of attitude. In regions where both contemporaneous volcanics and later intrusions are scarce or absent the Franciscan sediments have comparatively regular attitudes and exhibit few signs of crushing and shearing.

As a result of both late Jurassic and Tertiary intrusives both the sediments and volcanics may be strongly altered hydrothermally in zones of varying extent. When hydrothermal alteration is combined with deep burial and with crushing and shearing the beds, locally, may appear phyllitic or even slightly schistose. Such beds may be traced along their strike into practically unaltered rocks, outside the zone of shearing and hydrothermal alteration. In some places the Franciscan was so deeply buried that, when subjected to hydrothermal alteration, it recrystallized readily.

The glaucophane and related schists appear to be one of the chief causes for the common belief in the strong metamorphism of the Franciscan. However, these schists occur in small local areas on the borders of some of the basic and ultrabasic intrusives and never cover large areas. They are the result of local pneumatolytic contact metamorphism and not of widespread dynamothermal action. The entire question of the alteration of the Franciscan has been treated in some detail in the publications cited previously.

The primary manganese ores were deposited contemporaneously with the inclosing cherts and have passed through all of the complex events experienced by the Franciscan in general. Some of the deposits are so little altered that practically all original details are preserved,



below the oxide zone; others have been both hydrothermally altered and greatly crushed and sheared and many of the original relations have been modified, often largely obscured. However, none of the Franciscan deposits have been metamorphosed to the same extent as manganese deposits of the same type but of greater age in the Sierra Nevada.

### The Radiolarian Cherts

#### General Statement

Since the manganese deposits of the Coast Ranges practically always are associated with radiolarian cherts the field occurrence and petrographic character of these interesting rocks will be described in some detail. This is particularly necessary since an understanding of the mode of formation of the cherts should materially aid in an interpretation of the genesis of the manganese.

The best and most comprehensive treatment of the cherts is that by Davis.<sup>6</sup> Various phases of the subject have been discussed by the senior author.<sup>7</sup> The following discussion is based on the field observations of the authors; several hitherto undescribed relations will be treated. The chief emphasis will be placed on those phenomena that appear to have a direct bearing on the genesis of the manganese. Specific references to the literature will be avoided as far as possible. For many of the details the publications cited, all of which contain references to practically all of the known literature, should be consulted.

As stated previously the maximum development of cherts coincided with the beginning of maximum volcanism, which did not occur until a considerable thickness of rather coarse arkosic sandstones had accumulated in the sinking geosynclinal basin in which the Franciscan-Knoxville group was deposited. Geosynclinal sinking had progressed to at least 5,000 feet and possibly to 10,000 feet before the beginning of maximum igneous activity and the formation of siliceous chemical sediments and the iron and manganese deposits.

#### Lens-like Nature of the Cherts

The individual chert bodies vary enormously in size and extent, from a few feet to several miles in length and from less than a foot to several hundred feet in thickness. Where the relations have not been obscured by strong folding and crushing against rigid igneous bodies the chert bodies are clearly seen to be lenses inclosed in arkosic sandstones or in sandstones and shales. In many cases, however, the cherts rest directly on andesitic or basaltic flows, either with or without pillow structure. In such instances both flows and cherts are inclosed in elastic sediments. In following chert horizons, both large and small, it is not unusual to find several lenses at the same, or approximately the same, stratigraphic horizon.

<sup>6</sup> Davis, E. F., Radiolarian cherts of the Franciscan group: California Univ., Dept. Geol. Sci., Bull., vol. 11, pp. 235-432, 1918.

<sup>7</sup> Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, pp. 109-219, 1943.

Taliaferro, N. L., The relation of volcanism to diatomaceous and associated sediments: California Univ., Dept. Geol. Sci., Bull., vol. 23, pp. 1-56, 1933.

Taliaferro, N. L., Contraction phenomena in cherts: Geol. Soc. America Bull., vol. 45, pp. 189-232, 1934.

Taliaferro, N. L., Some properties of opal: Am. Jour. Sci., vol. 30, pp. 450-474, 1935.

The larger lenses are sometimes so thick and so extensive as to justify their separation as distinct formations, as has been done by Lawson,<sup>8</sup> in the San Francisco Bay region, but over most of the Coast Ranges even the larger lenses are not continuous for sufficient distances even to be mapped as members. Where mapping is carried out on the usual scale (approximately one mile to the inch) of the topographic maps in the Coast Ranges, only the larger bodies can be shown without gross exaggeration; these are, usually, less than a mile in length.

All of the bodies, whether large or small, appear as lenses. In some instances the smaller lenses may be the result of the disruption and shearing of longer lenses, but there are sufficient unmistakable examples to justify the statement that small lenses completely inclosed in coarse and fine clastic sediments occur along the same, or at many different stratigraphic horizons in the same region. Not only are the chert-shale bodies inclosed in fine to coarse clastics in the form of lenses but the individual chert layers are also lens-like in character. Furthermore, this feature does not end with the outer, visible form of an individual layer but, where such a layer exhibits any internal variations, they also are lens-like. This is likewise characteristic of the unoxidized manganese and iron deposits.

#### Association of Cherts and Volcanics

The very close association of cherts and volcanics, either basalts or andesites (with or without pillow structure) is common but not universal. In the southern Santa Lucia Range there is a very close relation between the two, and red and green radiolarian cherts and shales commonly both overlie and underlie pillow basalts. In this region there are an unusually large number of both flows and comparatively short chert lenses. As the flows decrease in number toward the northwest there is a corresponding decrease in the number of chert lenses.

A particularly striking example of the close spatial relationship between volcanic flows and cherts is found in San Luis Obispo County, north of the Cuyama River, in the Nipomo and Branch Mountain quadrangles. In this region andesite and basalt flows, often showing pillow structure, and having a maximum thickness of about 2,500 feet, are directly overlain by 900 feet of red chert and shale. Toward the northwest the flows decrease in number and thin and finally disappear. There is a corresponding thinning in the overlying cherts, which finally lens out at approximately the same point at which the flows end.<sup>9</sup>

In general there is a close field association between cherts and volcanics throughout the extent of the Franciscan and, usually, cherts are most abundant in regions where flows are most numerous. However, there is one notable exception to this general rule, namely, on the east side of the northern end of the Diablo Range, in Alameda and Stanislaus Counties. In this region red, pink, white, and green radiolarian cherts are interbedded with red and green shales and the chert-shale lenses are inclosed in fine to coarse sandstones, gravels, and conglomerates. These beds occupy the crest and flanks of the large Mount Oso anticline. Vol-

<sup>8</sup> Lawson, A. C., U. S. Geol. Survey Geol. Atlas, San Francisco folio (no. 193), 22 pp., 1914.

<sup>9</sup> Taliaferro, N. L., Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., vol. 27, fig. 7, p. 199, 1943.

canics are abundant at the top of the section on the north limb but only one thin flow has been observed where the chert lenses are most numerous. However, volcanics are abundant on the southwest limb and also at various horizons to the north. Thus, even in this region, there are contemporaneous volcanics both to the north and west.

The close association of volcanics and radiolarian cherts is not confined to the Franciscan but is world-wide. Even in California there are two older groups of rocks in the Sierra Nevada in which radiolarian cherts are closely associated with basic volcanics. These two older groups also contain manganese deposits.

#### Color of the Cherts

Nearly always the cherts are rhythmically banded with shales which usually have the same colors as cherts; red cherts are interbedded with red shales and green cherts with green shales. The colors of the cherts vary from white through various shades of pink and red to deep red, red brown, and chocolate brown, and from white through shades of pale green to dark green; sometimes they are yellow, yellow-brown, or buff, and, very rarely, they are black. The great bulk are either red or green, the red cherts greatly predominating. Not uncommonly red cherts contain thin lenses and irregular spots or splotches of green, and vice versa. The color also may vary along the same lens or from lens to lens in the same body. In some instances the green color is clearly secondary and the green cherts have red cores and are interbedded with red shales. However, in most cases the color appears to have been original, especially in the case of unaltered green cherts interbedded with green shales. In the following discussion of color variation only primary colors will be considered.

The writers have not observed any regularity in color variation in the lenses of rhythmically bedded cherts and shales. Green cherts are not concentrated either on the edges, the centers, or tops or bottoms of red chert-shale bodies. In other words, variation in color, which is chiefly due to a difference in state of oxidation of the iron, does not appear to have any definite relation to position within the chert-shale lens. Since the color appears to be an original feature, except in certain special cases that will be mentioned later, there does not appear to have been any constant relation between position in the original depositional environment and reducing conditions.

Secondary change in color in the cherts frequently takes place on the contacts of basic and ultrabasic intrusives. Colored cherts usually become white or gray on such contacts owing to the more or less complete recrystallization of the silica into a quartz mosaic and the aggregation of the originally evenly distributed coloring matter (usually iron oxide, either ferrous or ferric) into definite centers. Sometimes the iron enters into combination with other substances forming one or more of the characteristic contact minerals such as glaucophane or actinolite.

#### Thin-bedded Cherts and Shales

Davis<sup>10</sup> has given a very complete description of the physical appearance of the rhythmically bedded cherts and shales and hence it is

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<sup>10</sup> Davis, E. F., Radiolarian cherts of the Franciscan group: California Univ., Dept. Geol. Sci., Bull., vol. 11, pp. 235-432, 1918.

unnecessary to give a detailed account of all the possible variations. However, a brief statement of the more important features will be made.

Considering the chert-shale lenses in general there is a wide variation in proportion of chert and shale. However, in individual lenses there is a fairly constant relation between the two. Ordinarily the chert layers are thicker than the shales and range from about one-half inch to several inches, averaging less than two inches. Usually the shales vary from a mere film to several inches. Often entire lenses are made up of thin-bedded (1 to 3 inches) chert lenses separated by mere films of shales; but more commonly the shale interbeds have an appreciable thickness throughout the lens. Where the cherts predominate over the shales, which is the usual case, there is a sharp boundary between pure chert and shale. However, where small lenses of chert occur in rather thick shale beds, the cherts may be soft and shaly and the separation is not always sharp. This is especially true in the case of bright-red iron-rich shales; the cherts, in flocculating, appear to have included an unusually large amount of iron-rich clayey material.

In many cases a casual inspection of the ordinary lens gives the impression of great regularity of bedding, an impression that is not confirmed by careful examination. Even where the cherts appear to be most regularly bedded a close examination discloses the fact that the chert layers actually are lenses that pinch and swell and often terminate abruptly. Although the cherts usually are strongly folded and often greatly contorted, the original lens-like nature and frequent irregularities of the cherts are readily distinguishable from the effects of crumpling and shearing. The writers have examined thousands of chert-shale lenses, not only in the Franciscan but also in both older and younger rocks and have observed the same type of original irregularities of the chert lenses.

The original irregularities may be extreme and the cherts may appear as pinching and swelling and abruptly terminated lenses, separated by shale. Individual lenses may terminate either by gradual or rapid wedging or, less commonly, by the splitting of the lens into several parts by shale partings. The accompanying illustrations, both photographs and drawings from photographs, show some of the more important types of bedding of the cherts and shales. (Figures 3, 4, 5, and 6.)

#### Massive Cherts

There is one type of chert lens that has not been adequately described but which is of particular importance in the present discussion since it actually contains, or is closely associated with, the great majority of the manganese deposits of the Franciscan. This is the thick lens of massive chert that frequently interrupts the comparative regularity of the bedding and is inclosed in the thin-bedded cherts and shales. However, such massive lenses are not necessarily associated with manganese deposits but appear to be slight variants on the usual manner of aggregation of the silica. There are hundreds of these massive chert lenses only lightly stained with manganese, or containing no more than the ordinary cherts, for every one that contains, or is associated with, commercial deposits. Furthermore, there are many massive chert lenses that may be practically barren in one place and contain one or more small orebodies nearby.

It is not uncommon to find relatively thick lenses of massive <sup>11</sup> chert inclosed within thin-bedded cherts. Not every rhythmically bedded chert-shale body contains one or more lenses of massive chert but they are common. Massive lenses contain no shale or at best only occasional films of shale as partings, but otherwise they do not differ greatly in appearance from the ordinary thin-bedded cherts. They are always relatively thicker than the cherts in which they occur, and range from less than a foot to as much as 30 feet in thickness; their usual range is from 3 to 8 feet. Generally exposures are not sufficiently continuous to obtain any idea as to their maximum length. Lenses 6 or 8 feet thick may be 30 to 60 feet long but it is quite possible that the longer lenses may be several hundred feet in length. In places individual lenses of this kind occur repeatedly along the same stratigraphic horizon within the thin-bedded cherts. The writers have no information as to the possible localizations of such lenses, whether marginal or central, but they usually occur well within the chert-shale bodies rather than at the top or bottom. However, there are examples of massive cherts near the bottom or top and one known example of a massive lens that rests upon a 4- to 5-foot bed of arkosic sandstone that in turn rests upon thin-bedded cherts and shales. Both the massive chert and the sandstone are inclosed within rhythmically bedded chert and shale and are parallel with the bedding above and below.

The massive chert lenses usually have rather blunt wedge-like terminations, but like the small irregular lenses they may rarely terminate by gradual thinning and the appearance of marginal shale partings. The disturbance in the rhythmic bedding of the inclosing thin-bedded cherts and shales is compensated for either by the wedging out of the thin beds of chert and shale or by the beds wrapping about the ends of the massive lens. The massive lenses pinch and swell in the same manner as the small lenses; the thin layers in contact with the massive chert tend to conform to its irregularities.

Generally the color of these more massive lenses is paler than the inclosing thin-bedded cherts. The color varies from white or gray to pale green, pink, or red; some are yellow, buff, or red-brown. In some instances there is little or no difference in color between the thin-bedded cherts and the massive cherts that break the uniformity of the rhythmic bedding.

#### Cherts with Limestones

In a few localities cherts are closely associated with foraminiferal limestones, sometimes even interbedded with them. Two types of chert may be recognized, one a typical red radiolarian chert interbedded with red, gray, and white limestone, the other irregular branching lenses and nodules of gray to black flint apparently replacing the limestone. The best example of red radiolarian cherts interbedded with foraminiferal limestone is in Mendocino County, about 2 miles north of Laytonville, along the east side of Highway 101. Here there is a moderately thick lens of white to gray foraminiferal limestone inclosed in arkosic sandstone; volcanics also are present nearby. Toward the southern end of this lens the limestone becomes pink to bright red and is interbedded with

<sup>11</sup> E. F. Davis (*op cit.*, pp. 247, 263) refers to massive cherts as those containing shale partings that are mere films. This is not the sense in which the authors are using the term "massive chert."

thin (up to 6 inches) lenses of red radiolarian cherts. As the limestone lenses out the red cherts are interbedded with slightly calcareous red shales. Both the cherts and the limestones are inclosed in arkosic sandstones, dark shales, and volcanics. In several places in the Coast Ranges south of San Francisco Bay small lenses of foraminiferal red limestone have been found interbedded with red cherts and shales.

#### Environment of Deposition of the Cherts

The very close association of the cherts with fine and coarse clastics of the Franciscan and the frequent interbedding of the various types indicate that they were deposited in a shallow marine environment. Sufficient evidence has been presented in the publications cited to show that the radiolarian cherts were not deposited in the deep abyssal zone but in comparatively shallow water, even in the shallow neritic zone. However, the localization of the cherts probably required local variations in bottom configuration.

It has been suggested that the chert-shale lenses were formed in submarine depressions or basins of sufficient depth to prevent the influx of coarse sediments and in which the silica-rich oozes could accumulate quietly in the absence of disturbing currents. There are no direct field observations to support this hypothesis, which is based on theoretical reasoning. The writers have observed no field evidence that would support the hypothesis of deep stagnant basins. It appears obvious, however, that checks or dams of some type were required to localize the accumulation of these silica-rich oozes, that by flocculation and coagulation of the silica resulted in the rhythmically bedded cherts and shales, and these places of accumulation may have had the form of shallow depressions. There is nothing that would indicate the presence of deep basins; furthermore, there are certain facts that show that deep basins either did not exist or were not the controlling factor in chert formation and localization.

In the first place there is nothing in the character of the cherts and shales that would indicate deposition in stagnant basins. The abundance of Radiolaria in the cherts and shales indicates rather abundant pelagic life. If stagnant basins had existed the shales, at least, should show the effect of long-continued accumulation of decomposing organic matter and characteristic black organic shales should have formed. Organic shales of this type never are found in association with the cherts.

In the second place it is not uncommon to find chert lenses separated by coarse sandstones and even pebble or cobble conglomerates. In places rather rapid alternations of thin chert-shale lenses and sandstones and conglomerates are a usual feature.

In the third place cherts sometimes occur as rhythmically banded lenses in medium- or even coarse-grained arkosic sandstones without any shale partings. Also, coarse sandstones may occur as lenses in chert and shale.

Furthermore the frequent occurrence of innumerable small lenses of rhythmically bedded chert and shale inclosed in arkosic sandstones at numerous horizons in the same section and in trains of small lenses along the same horizon does not favor the theory of deposition in deep basins. In fact the size of the basins in which such small lenses were deposited could have no appreciable effect on currents.

The writers have no intention of stating that the chert-shale lenses were not formed in depressions, but believe that most of the depressions need only to have been slight irregularities of bottom configuration probably no greater in depth, below the prevailing submarine level, than the thickness of the chert-shale lenses. The close association and frequent interbedding of coarse elastics and cherts indicate that both were formed in the same general physical environment. It is the writers' contention that the observed facts do not indicate that the formation of the cherts required special or unusual depositional environments. They maintain that there is nothing to substantiate the theory of deposition of the cherts in deep stagnant basins where reducing conditions would prevail. If this is true of the cherts it is equally true of the manganese and iron deposits associated with them.

#### Petrography of the Cherts

Hundreds of thin sections of cherts and the manganese ores associated with them have been studied under the microscope. The results of the microscopic examinations of the cherts will be briefly summarized.

As pointed out previously the Franciscan often has been buried beneath as much as 40,000 feet of later sediments and has been folded and faulted a number of times. Furthermore the sediments have been crushed against the more resistant contemporaneous flows and later intrusions and have been hydrothermally altered in a number of places. Therefore, it is only natural that the sediments should have been altered somewhat during the long and complex history through which they have passed; it is surprising that the alteration has not been greater.

Most of the cherts have been converted to a cryptocrystalline or fine granular aggregate of chalcedony or a very fine mosaic of interlocking quartz grains; the interbedded shales may be practically unaltered or slightly slaty. However, in some instances, the cherts have not been crystallized to chalcedony and quartz, or to quartz, and are still largely composed of amorphous silica colored red or green by iron oxide. There can be little doubt that the cherts originally were opal, colored in varying degrees by iron, and in some cases, manganese oxide.

All degrees of crystallinity between amorphous silica and rather coarsely crystalline quartz-rocks may be observed; the degree of crystallinity appear to be a function of the degree of local alteration.

Medium to coarsely crystalline quartz-rocks appear to result from both igneous intrusion and intense local deformation and veination. On the contacts of basic and ultrabasic intrusives, without addition of material from the magmas, the cherts simply recrystallize to a quartz mosaic with the formation from the impurities present of minerals such as biotite, chlorite, and hematite. With the addition of material from the magma (pneumatolytic metamorphism) minerals such as glaucophane, garnet, and sphene may form, resulting in glaucophane-garnet-quartz rocks. The pneumatolytic alteration of the cherts and other Franciscan rocks has been fully discussed previously.<sup>12</sup>

Radiolaria are nearly always present both in the cherts and the interbedded shales but they are not evenly distributed and often vary greatly in numbers in the same thin section, being closely packed in some

<sup>12</sup> Taliaferro, N. L., Franciscan-Knoxville problem: *Am. Assoc. Petroleum Geologists Bull.*, vol. 27, pp. 159-182, 1943.



bands and scarce or wanting in others. Some thin sections may be entirely free from Radiolaria. In the opaline cherts, and even in those that are cryptocrystalline, or finely crystalline, the Radiolaria may be well preserved and the spines and even details of wall structure may be made out under the microscope. Specific determinations can not be made and even generic assignments are unreliable but it is certain that the main orders, *Nasselaria* and *Spumellaria* are well represented. Radiolaria occur in cherts of all colors but they stand out most clearly in those in which iron and manganese oxide, or manganese oxide, are most abundant.

The opaline and chalcedonic cherts break with a smooth, conchoidal fracture but those that are well crystallized break with an uneven or hackly fracture.

The lens-like nature of the rhythmically bedded cherts, previously described, is recognizable even on a minute scale under the microscope. Thin sections of individual chert lenses and layers frequently show a definite banding that is commonly lens-like in character. The various lenses are the result of uneven distribution of color, impurities, and Radiolaria. Color, which is the chief cause of the banding, is dependent on the amount of red iron oxide in the chert. Some lenses and layers are highly charged with ferric oxide and, therefore, are deeper in color. Minute quantities of mechanically entangled impurities are also responsible for some of the faint banding observable under the microscope. Both microscopic and megascopic banding become more pronounced when manganese, either as the oxide or carbonate, becomes abundant in a chert layer.

#### Chemistry of the Cherts

Few complete analyses of Franciscan cherts are available but there are enough to give a reasonably accurate picture of their general nature. Usually in the case of the red chalcedonic cherts, silica ranges from 93 to over 96 percent, alumina is a little over 2 percent, and iron oxides from 1 to 3 percent. Small quantities of manganese oxide, magnesia, lime, water, and the alkalis are present. The alumina, magnesia, lime, and alkalis represent the small amount of fine clayey detritus mechanically entangled when the colloidal silica was flocculated.

There are no complete analyses of opaline Franciscan cherts available, but such cherts should show a much higher percentage of water than the chalcedonic cherts.

#### Veining and Brecciation of the Cherts

Veining and brecciation of the cherts are briefly described because exactly similar phenomena are shown by the manganese deposits.

Excluding those along igneous contacts and on or near faults, the veins in the cherts are, as a rule, very thin, being rarely over 0.10 inch and ranging downward to those visible only under the microscope. Both the degree of veination and the size of the veins appear to be directly related to the degree of deformation and contortion of the cherts. In the same outcrop the number and size of the veins vary considerably, being larger and more numerous where the chert beds bend about small contortions and minor wrinkled folds. Only the larger veins extend into the interveining shale layers, the majority being confined to the individual



chert layers. Usually the veins are of quartz or chalcedony and stand out as faint or rather strong ridges on bedding surfaces. The accompanying sketch, figure 2, is made from a bedding surface of a thin-bedded red radiolarian chert, from 0.55 to 0.75 inch in thickness. The veins are of chalcedony and show on the bedding surface as very faint to rather well-defined ridges. The particular piece from which the illustration was sketched forms part of a lens of red and green radiolarian chert and shale that has not been contorted but dips  $50^{\circ}$  to  $65^{\circ}$  S. The number of veins is not unusual.

The veins appear to have developed in place along joints. Occasionally one vein is very slightly offset by another, but usually they cross each other without deviation. The chief movement appears to have been at right angles to the walls, as shown by the splitting apart of *Radiolaria* in the path of the vein. Practically always the veins are clear and uncolored by iron or manganese oxide, except in the vicinity of orebodies, and stand out sharply from a background of red chert, especially under the microscope. They appear to represent the growth of chalcedony or quartz in place.

Excluding the brecciation along fault zones, which may be extreme, the cherts are commonly brecciated, especially at the turns of minor contortions. The brecciated layers usually have been recemented by quartz and chalcedony similar to that in the veins. Sometimes the bedding brecciation is so severe that fragments of the chert appear to be floating in quartz or chalcedony.

The manganese deposits exhibit the same phenomena of veining and brecciation. The vein material may be quartz, chalcedony, manganese carbonate or any one of a number of hydrous manganese silicates.

#### Original Form of the Silica in the Cherts

Many lines of evidence lead to the unescapable conclusion that the silica forming the cherts was originally present as a colloid. The writers believe that the chert-shale lenses were, originally, highly siliceous oozes made up of a mixture of colloidal silica, iron oxide, or more probably ferric hydroxide, and finely divided clayey material. This was localized either in shallow depressions or simply as small rather coherent masses anywhere on the sea bottom. From the fact that in the great majority of chert-shale lenses the ratio of chert to shale is usually 3 or 4 to 1, or even more, it is evident that colloidal silica was the most abundant constituent of the oozes. It is a well-known fact that when colloidal silica passes from the sol to the gel stage it has the ability to free itself from mechanical impurities such as clayey, or even coarse sandy material. In the case of the Franciscan cherts, where colloidal silica was greatly in excess of fine mechanical sediments the separation appears to have been practically complete and there is a sharp boundary between each almost pure chert and the shale layers. A small amount, usually not over 4 or 5 percent, of clayey impurities was entangled with the colloidal silica that formed the chert. However, when there was a small amount of silica in a large amount of fine clayey material the separation was not as perfect and a considerable amount of clayey material was entangled with the colloidal silica. This appears to be the explanation of the small impure red chert lenses in thick layers of red shale.

The rhythmic banding of the cherts and shales does not represent either seasonal alternations or sudden influxes of colloidal silica alternating with influxes of fine sediments but represents segregation from a highly siliceous ooze by flocculation of the silica. It is a diffusion phenomenon somewhat analogous to Liesegang rings. Rhythmic alternations of colloidal silica and fine clayey material were produced artificially in the laboratory by Davis.<sup>13</sup>

The rapidity of hardening and the entire process of the passage of colloidal silica from the sol stage, through gels into the final cherts already has been discussed<sup>14</sup> and the arguments and conclusions need not be repeated here in detail. It is sufficient to state that there is abundant evidence that the gels passed rapidly into the true opaline chert stage and that hardening was a matter of days or, at the most, months, rather than of years.

Contraction phenomena resulting from dehydration of the first-formed, water-rich opaline cherts are of rather common occurrence in practically all types of Franciscan cherts as well as in the manganese deposits associated with them. Contraction phenomena in general have been discussed in previously cited papers.

It has been shown, in the publications cited, that colloidal silica, when flocculated or coagulated, has the power to rid itself of practically all mechanical impurities but, on the other hand, it will absorb, or actually incorporate in the gel an almost unlimited amount of other colloidal material or substances in solution. That it rids itself of the clayey impurities is shown by the clean-cut rhythmic bedding of chert and shale. It has been shown<sup>15</sup> that calcium carbonate may be included in silica gels in amounts up to 40 or 45 percent by volume and still permit the gel to consolidate into a chert-like rock (porcelanite), passing through all the usual phenomena of contraction and consolidation shown by pure chert. Manganese carbonate appears to behave in the same manner. Manganese and calcium carbonate are not excluded by the consolidating silica gel but remain in the rock as mechanically included substances. Both may have been present in the silica-rich ooze in the colloidal form or in solution and hence were not excluded as the silica passed from the original fluid sol stage, through the gel stage, into an opaline chert.

Microscopic examination shows that both iron and manganese oxides can enter into the silica gel in variable quantities, probably up to 50 percent, and still produce a homogeneous isotropic substance having many of the properties of opaline cherts.

Discussion of the possible source, or sources, of the silica will be deferred until the manganese and iron deposits are described, as it is believed that the silica, manganese, and iron are so closely and so generally associated in the Franciscan that they were derived from essentially the same source, or sources, and introduced into the sea water in essentially the same manner.

<sup>13</sup> Davis, E. F., *op. cit.*

<sup>14</sup> Taliaferro, N. L., Contraction phenomena in cherts: *Geol. Soc. America Bull.*, vol. 45, pp. 189-232, 1934.

Taliaferro, N. L., The relation of volcanism to diatomaceous and associated siliceous sediments: *California Univ., Dept. Geol. Sci., Bull.*, vol. 23, pp. 1-56, 1933.

<sup>15</sup> Taliaferro, N. L., Contraction phenomena in cherts: *Geol. Soc. America Bull.*, vol. 45, pp. 196, 197, 226, 1934.

## THE MANGANESE DEPOSITS

### General Statement

Not only are the manganese deposits of the Franciscan practically always associated with the radiolarian cherts but also they are, nearly always, associated with a particular kind of chert. Field observations over the entire extent of the Coast Ranges show that all of the important deposits (and, in fact most of the unimportant deposits) are intimately associated with the massive cherts that so frequently interrupt the rhythmic bedding of the thin-bedded cherts.

There are all gradations between cherts that are merely stained and filmed with black manganese oxides, derived from very small quantities of manganiferous chert or manganese carbonate, through low grade, highly siliceous ores to rather pure manganese carbonate. A very small amount of black manganese dioxide can stain and film the surface and fracture cracks of large chert outcrops but such staining is not, necessarily, indicative of the presence of commercial deposits. Scores of prospects, based only on thin films and surface coatings, have been visited. Such stained outcrops when broken show the presence of normal red, or less commonly green, chert beneath. Although some of these stained cherts have been of importance in connection with the study of the genesis of the ore they are not included in any of the following statistical summaries regarding the size of the orebodies.

Naturally there is a wide variation in types of exposures and degree of oxidation of the ore. Some orebodies are well exposed in natural outcrops or in mines and prospects and the relations of orebodies to enclosing rocks are well shown. In a few instances, ore has been mined from loose blocks lying in the soil. Naturally these latter afford little information regarding mode of occurrence. In some cases faulting and shearing have so disrupted and modified the original form and relation of the orebodies that no reliable observations are possible. However, the original relations are preserved in the majority of cases and there can be no question regarding the fact that the ores are interbedded with cherts.

Oxidation of the original substances to black manganese oxides is universal but varies from mere films to depths of many feet. The writers have observed all gradations from cliff exposures of carbonate ores where the oxidation was a mere surface film to those deposits in which oxidation had extended to scores of feet beneath the surface. Some of the prospects have not been worked to a sufficient depth to reach the bottom of the zone of oxidation; but even in most of these, cores of the original, unoxidized substances are found. In no instance is there any suggestion that the black oxides of manganese constitute the primary minerals.

The original ores, particularly manganese carbonate, oxidize readily. Manganese carbonate specimens kept in drawers in the laboratory will tarnish and become filmed with a black oxide in the course of a few years. On the dump of the Ladd mine large blocks of original brown carbonate ore exposed for a few months to the atmosphere became filmed and tarnished with black oxides; however, the lower parts of the blocks, buried in finely broken material and somewhat protected, were not oxidized to any extent. The black oxides also have the troublesome ability to migrate in solution and, in places, may penetrate the wall rocks of orebodies as films and surface coatings, thus giving a false impression

of the width of the orebody. The true width, however, is readily determined by investigation.

The observations and conclusions given in the following pages are based on an examination not only of all the known economically important deposits but also on a large number of very small deposits and prospects.

#### Size of the Orebodies

None of the orebodies are of great size; workable beds of manganese ore range from a few inches to as much as 27 feet in thickness (Ladd mine, San Joaquin County, has the thickest orebody known to the writers). An average of more than 50 examples of workable beds gives a width of a little less than 4 feet, but not all of these are high-grade ore. There is no relationship between size and grade; some low-grade ores, really manganeseiferous cherts, may be from a few inches to more than 20 feet thick.

Less is definitely known regarding the lengths of orebodies than the thickness. This is largely because of the many periods of diastrophism which have affected the Franciscan. Transverse faults, usually of rather small throw, are very numerous and therefore orebodies of any appreciable length are frequently offset. In the absence of good exposures it is sometimes difficult to determine if some of the discontinuous deposits are separate lenses or the faulted parts of a long lens. However, it is known that some of the larger orebodies are 600 feet or more in length. Usually the thicker the orebody the greater its lateral extent, but a few orebodies as much as 6 or 8 feet thick occur as short stumpy lenses.

Although it is known that the orebodies occur as lenses included in and parallel with the bedding of the cherts practically nothing definite is known regarding their original ground plan. This is equally true of the chert lenses. It is commonly assumed that they are circular or elliptical in plan but of this there is little proof except that some of the smaller lenses, both of chert and ore, have this general outline. It must be remembered that the Franciscan is strongly folded and stands at high angles and that only two dimensions are seen.

#### Nature of the Original (Syngenetic) Ores

Before discussing the details of the form and association of the orebodies the character and composition of the original ores will be discussed.

First, it is necessary to define what is meant by the term "original ore" and why this expression is used rather than "primary ore." The latter term does not convey the authors' idea since it is so commonly used for various sulphides and other minerals below the present, or any former ground-water level, which have not been altered, leached, or enriched to any appreciable degree since they were formed. However, such primary orebodies may have been emplaced long after the time of formation of the rocks in which they are found. By the term "original ore" the writers mean syngenetic ores that were formed contemporaneously with the inclosing chemical sediments. Hereafter they will be referred to as syngenetic or original ores.

Some of the syngenetic deposits have been altered by hydrothermal action and changed into other forms, with or without remnants of the original material. Some have been pneumatolytically metamorphosed on the contacts of basic and ultrabasic rocks. Many have been slightly recrystallized by folding or the weight of superincumbent strata. Prac-

tically all types, including the unaltered deposits, are greatly veined with quartz, chalcedony, and various manganese silicates (usually hydrous) and manganese carbonate just as the ordinary cherts are veined with quartz and chalcedony.

Essentially, there are two types of original substances forming the syngenetic orebodies, which may be predominantly of one or the other or, more commonly, of mixtures of the two in all proportions.

Probably the most abundant material in the original deposits, and certainly the one which yields the best oxide ores, is manganese carbonate, usually in a very finely divided state. The other material, nearly as abundant as the carbonate, and making up the great bulk of several deposits, is a brown manganiferous opal.

Pure, or relatively pure, unoxidized manganese carbonate is usually light to dark gray on freshly broken surfaces and is quite similar in appearance to many of the gray limestones in the Franciscan. However, many of the carbonate ores are light to dark brown because of the presence of varying proportions of the brown manganiferous opal. The carbonate and mixed carbonate-manganiferous opal ores are commonly cut by veins of pale to deep pink crystalline rhodochrosite just as many limestones are cut by veins of crystalline calcite. The gray manganese carbonate is, essentially, made up of spherulitic to fine-grained rhodochrosite, and gives an X-ray pattern characteristic of that material, just as limestones are made up of finely divided calcite; but it is no more appropriate to call the manganese carbonate ore rhodochrosite than it would be to call the ordinary dense limestone calcite. The name rhodochrosite will be restricted to the pink crystalline variety of manganese carbonate occurring as veins and irregular areas within or near the dense manganese carbonate rock.

Usually the manganese carbonate is an exceedingly dense fine-grained aggregate similar in appearance, both in the hand specimen and under the microscope, to many dense limestones. Not infrequently it is made up of an aggregation of closely packed spherules, made up of minute fibers radiating from a common center and showing the usual extinction cross.

Not only does manganese carbonate occur in definite lens-like orebodies but also scattered through both massive and thin-bedded chert; it is more abundant in the massive than the thin-bedded varieties. The oxidation of small amounts of manganese carbonate is a common cause of the thin film of black manganese oxide on otherwise barren cherts. Spherules of carbonate may occur either scattered at random through the chert or arranged in a definite zone along which they may become more and more abundant, finally forming a small lens a few millimeters in length. These minute lenses are in every way similar to the orebodies except for size. In fact, there is every transition between such almost microscopic lenses and workable orebodies.

When little altered by pressure the manganese carbonate is spherulitic but the individual spherulites take on the form of a rhomb as they crystallize. Stages in this change have been observed under the microscope. On one hand may be seen spherules made up of minute fibers radiating from a common center and on the other small rhombs of manganese carbonate of the same size. Apparently between the two are poorly formed rhomb-shaped areas still showing the fibers radiating from a common center. The well-formed rhombs occur in the more com-

pletely recrystallized cherts. Spherules and rhombs may be imbedded either in ordinary radiolarian chert or in manganiferous opal. Their size varies from a fraction of a millimeter to over a millimeter.

The deposits of manganese carbonate are not the result of leaching of the carbonate from the surrounding chert and its redeposition as a rather pure bed of carbonate ore, as neither the spherules and rhombs, nor the cherts in which they occur, show any sign of leaching; the manganese carbonate is still in its original form, except when oxidized. Furthermore, lenses of carbonate ore may develop by the coalescence of several trains of spherules or rhombs in ordinary chert or in the brown ore.

Fairly pure beds of carbonate are not uncommon and are found throughout the Coast Ranges. However, there are but two chemical analyses of comparatively pure carbonate ore available and both are from the same lens. At the Brereton mine in Mendocino County, 7 miles east of Covelo (SW $\frac{1}{4}$  sec. 31, T. 23 N., R. 11 W., M. D.) there is a bed of rather pure carbonate ore as much as 4 feet in thickness which lies on one side of a massive bed of chert about 12 feet thick. Ore and massive chert are inclosed in thin-bedded red and greenish chert and shale approximately 50 feet thick. This entire lens lies in typical coarse arkosic sandstones in which thin lenses of red chert and shale are numerous. Four hundred feet west of the thick bed of carbonate is a lens of thin-bedded red and greenish chert about 40 feet thick that contains, near the center, a thin lens of carbonate ore, largely oxidized, 1 to 2 feet in thickness.

A small open cut was made on the larger carbonate lens and the original ore exposed. Since this deposit is at an elevation of approximately 2300 feet and is on the steep east bank of the Middle Fork of the Eel River, oxidation has not extended to any great depth. The original ore, beneath the oxidized shell, is a dense light to dark gray carbonate. Owing to strong folding and the presence of diabase intrusions the rocks have been somewhat recrystallized and the grain of the carbonate has been slightly coarsened. Even so the average grain size is not over 0.20 mm. Veins of well-crystallized pink rhodochrosite up to 8 mm in diameter are numerous.

The following are analyses of the gray carbonate, made on material free from veins of rhodochrosite.

*Analyses of gray manganese carbonate from a 4-foot bed in the  
Brereton mine, Mendocino County*

	I	II
SiO <sub>2</sub> -----	3.50	4.42
Al <sub>2</sub> O <sub>3</sub> -----	.35	n.d.
FeO -----	Trace	Trace
Fe <sub>2</sub> O <sub>3</sub> -----	1.05	2.00
MnO -----	61.10	61.30
CaO -----	1.02	0.21
MgO -----	0.75	1.14
K <sub>2</sub> O and Na <sub>2</sub> O -----	nil	n.d.
H <sub>2</sub> O— -----	nil	n.d.
H <sub>2</sub> O+ -----	0.10	0.20
CO <sub>2</sub> -----	31.80	30.40
P <sub>2</sub> O <sub>5</sub> -----	0.25	n.d.
BaO -----	nil	n.d.
	<hr/> 99.92	<hr/> 99.67

I. Analysis by Herdsman, Glasgow.

II. Analysis by N. L. Taliaferro.

Two analyses of the black oxide ore, resulting from the oxidation of the gray carbonate, were made by A. A. Hanks, San Francisco, with the following results:

Mn -----	54.16 (MnO <sub>2</sub> 84.03)	56.22 (MnO <sub>2</sub> 87.23)
SiO <sub>2</sub> -----	5.75	3.85

Thus this carbonate deposit gave rise to a high-grade black oxide ore.

There is not a sufficient amount of carbon dioxide to unite with all of the manganous oxide, lime, and magnesia to form the various carbonates. If the lime and magnesia are united with the carbon dioxide to form carbonates there is a small excess of MnO. That this is actually the case is shown by a microscopic examination of the carbonate ore. Under the microscope there are seen to be thin contorted lenses made up of minute fibers of a pale-yellow to deep-brown or orange-brown mineral. Qualitative chemical tests show the lenses to be composed essentially of MnO (MnO<sub>2</sub> when oxidized), SiO<sub>2</sub>, and H<sub>2</sub>O. However, these three constituents do not appear always to be present in the same proportion, a result that is confirmed by the fact that fibrous material making up the lenses shows wide variation in color, index, and birefringence. It is believed that this material has resulted from the crystallization of the original manganiferous opal, just as ordinary opal crystallizes into chalcedony. The exact composition of the various minerals that have been formed is not known but they are, essentially, hydrous manganese silicates of variable formula. Some of these may correspond to the bementite type of silicate. Lenses of this kind are commonly contorted when they occur in rather pure manganese carbonate that has been completely crystallized, probably because of internal movements within the easily deformed carbonate. When little altered they are parallel to the bedding.

Comparatively pure lenses of manganese carbonate are widely distributed in the Coast Ranges both north and south of San Francisco Bay. Excellent examples are found at Blands Cove, Brereton mine, and on the west face of Impassable Rock in Mendocino County. One of the ore-bodies in the Buckeye mine (Stanislaus County) is largely of manganese carbonate. These are but a few of many examples. (See figures 10 and 11.)

Carbonate lenses are invariably cut by veins of well-crystallized pink to rose-red rhodochrosite. It is possible that the pale-colored varieties actually are manganocalcite. There are not a sufficient number of analyses either of the pure carbonate lenses or the rhodochrosite veins to justify any statement as to the extent to which calcium carbonate is present.

Almost as abundant as manganese carbonate as an original syngenetic substance is a brown manganiferous opal of variable composition. Although some deposits are essentially made up of this type of material, variable amounts of manganese carbonate are always present. Even the best of the carbonate deposits contain some manganiferous opal; mixed deposits containing both carbonate and opal are much commoner than relatively pure carbonate or opal lenses.

The brown ore, even when unaltered, is quite variable in color, lustre, fracture, composition, and refractive index. When almost free from carbonate it has a marked resinous lustre and breaks with a conchoidal fracture; miners call such ore "rosin jasper." Since there is a



wide variation in the proportion of manganous oxide in the manganiferous opal there is a wide range in color but brown is the predominant shade. Even in those unoxidized deposits containing, on the average, over 40 percent of manganous oxide there is a considerable range in shade in a single lens and even in a single thin section. This is caused by internal banding, parallel to the bedding; the individual bands and lenses contain variable amounts of manganese oxide. The color ranges from rather pale yellow brown, through various shades of brown to liver brown, red brown and chocolate brown. The same shades are observed under the microscope. It alters to a lustrous black oxide high in silica. Oxidized ores, above such deposits, nearly always contain spongy cores of white opal or chalcedony. Oxide ores derived from such deposits are, usually, lower in manganese and higher in silica than those from relatively pure carbonate ores.

Under the microscope the unaltered material is seen to be isotropic. Nearly always, however, even in the least altered examples there are hazy ill-defined areas showing faint birefringence in the midst of the isotropic base. Spherules of manganese carbonate are usually present; these sometimes become abundant and coalesce to form a lens just as they do in the cherts. Radiolaria are commonly present. (See figures 12, 13, and 14.)

The best example of a fairly thick lens (as much as 4 feet) of rather pure, little-altered manganiferous opal occurs at the Wood mine (now called the Charles Mountain mine) in Sec. 3, T. 1 S., R. 4 E., H. This is 12 miles by road northwest of Blocksburg, Humboldt County. At this mine there are two ore lenses, both of which are frequently offset by small transverse faults. Both occur in rather gently dipping thin-bedded red radiolarian cherts and shales. The lower bed is 2 to 4 feet in thickness and is a typical resinous brown manganiferous opal containing as much as 15 percent of manganese carbonate in the form of spherules and small lenses. This gives rise to a fairly good grade of black oxide ore ( $Mn = 46.49$ ,  $SiO_2 = 20.48$ ). The upper bed, about 100 feet higher topographically, is 15 inches to 4 feet in thickness and is lower in manganese. This upper bed grades eastward into a massive manganiferous red chert that differs little in appearance from the thin-bedded red radiolarian cherts in which it is inclosed except that it oxidizes on the surface to a black manganese oxide ore. This lens is not uniform throughout but is banded parallel to the bedding, the bands being in the form of lenses having a variable manganese content. Some of the lenses are pale brown, others are dark red brown and resinous. That part of the massive lens that might be called ore fades out into a massive red chert containing small lenses and streaks of manganiferous opal and spherules of manganese carbonate. Here there are all gradations between ore and manganiferous chert in the same lens. Figure 16 is a photograph of a polished surface of banded chert and ore oxidizing to black manganese oxides on the surface.

Under the microscope the least altered resinous brown ore is seen to be largely isotropic, but with hazy ill-defined areas showing very weak birefringence. Spherules of manganese carbonate make up 10 to 15 percent of some of the slides. Radiolaria are not uncommon and many different genera appear to be present. Sometimes the Radiolaria are partially or completely replaced by either manganese opal or carbonate





Fig. 1. Relief map of California showing position of the Coast Ranges. *Model by N. F. Drake, 1896. Stanford University.*

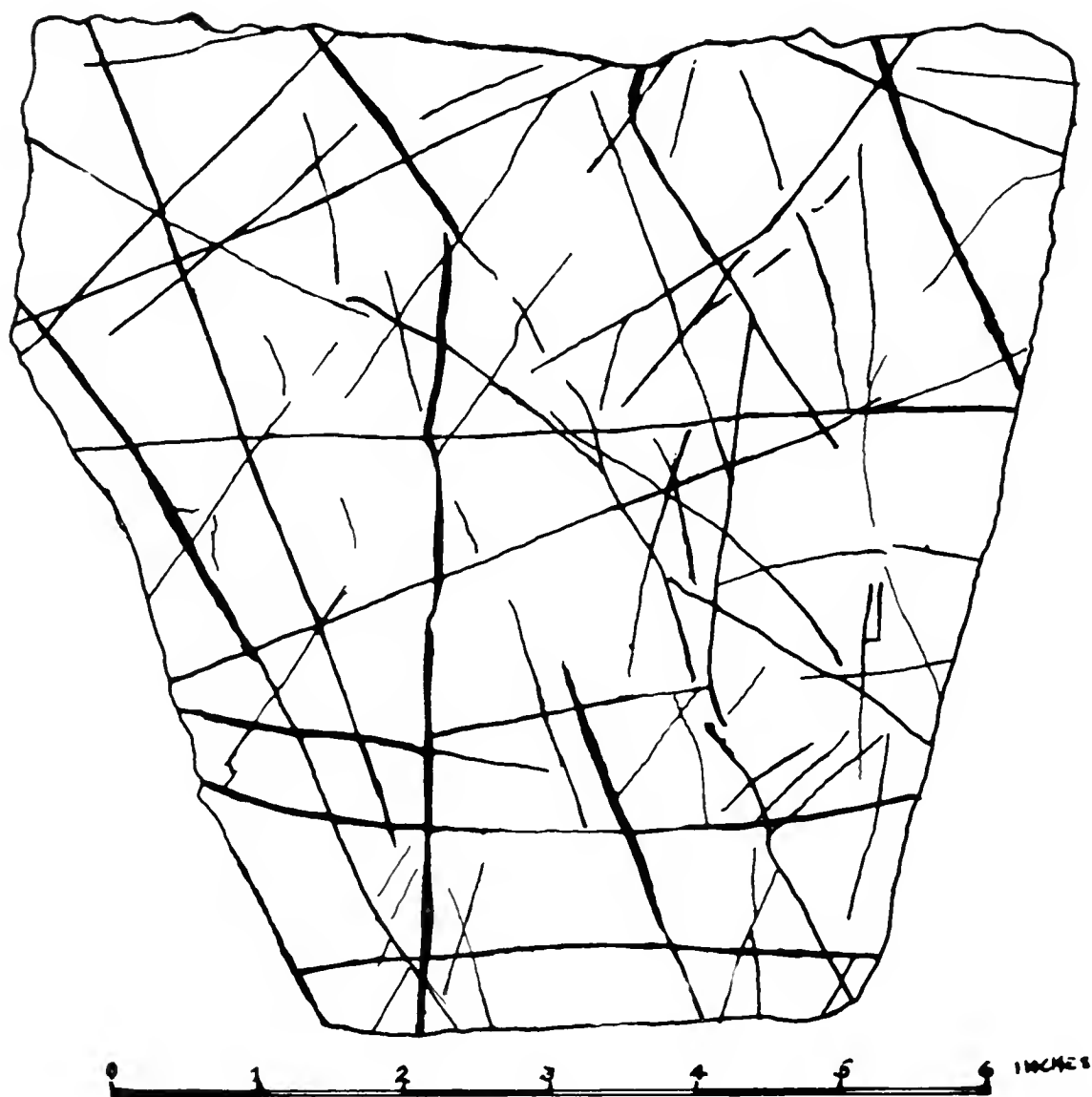


Fig. 2. Quartz and chalcedony veins in thin-bedded red radiolarian chert, interbedded with soft red shales; the veins do not cut the shales but are confined to the thin chert lenses. Traced from the surface of a chert layer 0.55 to 0.75 inch in thickness. Many of the ore lenses show a similar vein pattern. Hospital Canyon, Carbona quadrangle, near line between Stanislaus and San Joaquin Counties.

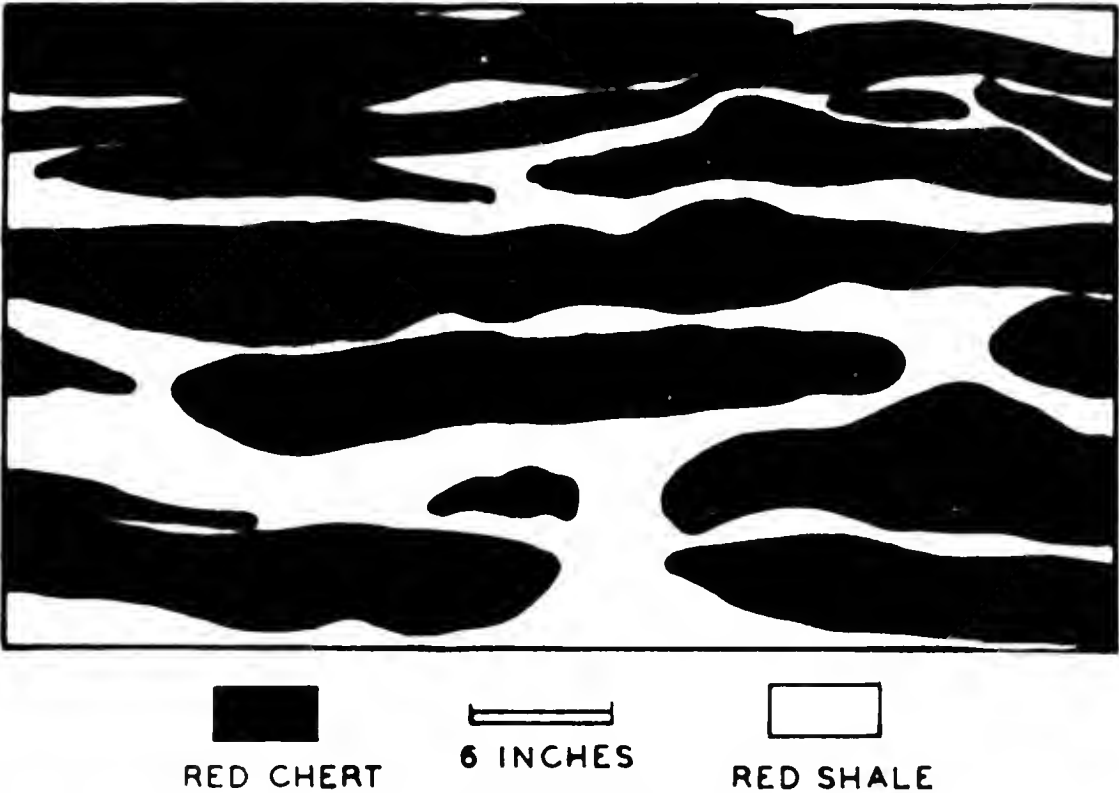


Fig. 3. Irregular nodular pinching and swelling lenses of chert in shale. Twin Peaks, San Francisco. Traced from photograph.

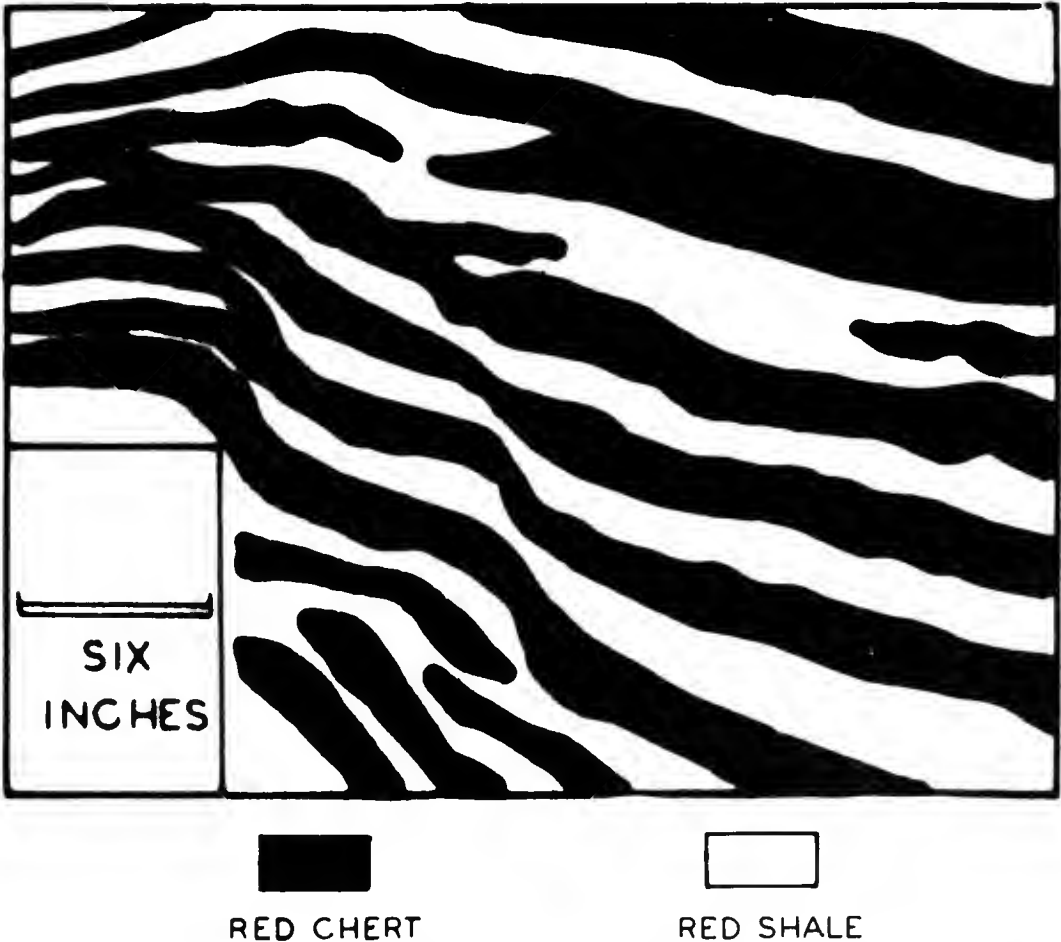


Fig. 4. Irregular lenses of red radiolarian chert and shale, somewhat contorted by folding. This rests directly on spilitic pillow basalts. Traced from photograph. San Simeon quadrangle, west side of Santa Lucia Range.



Fig. 5. Thin-bedded pink and green radiolarian chert with almost paper-thin gray-green shale partings. The thick stubby lens, near the center, is characteristic. Larger, ore-bearing lenses often occur in this manner. Scale is 6 inches long. Hospital Canyon, Carbona quadrangle, on line between Stanislaus and San Joaquin Counties. Lenses of manganese ore occur in this chert-shale lens less than a mile to the east.



Fig. 6. Typical exposure of typical slightly crumpled thin-bedded red radiolarian chert and shale. Quarry (for road metal) on English Hill Road, 3 miles southwest of Sebastopol, Sonoma County.



Fig. 7. Thin-bedded red radiolarian chert and shale. Old abandoned road to Buckeye mine, Carbona quadrangle, Stanislaus County. Although exceptionally well bedded, the lens-like nature of the cherts is apparent on close examination.





Fig. 8. Lenses of massive chert in thin-bedded chert and shale; crumpled and folded. Buckeye mine, Carbona quadrangle, Stanislaus County.



Fig. 9. Buckeye manganese mine, Carbona quadrangle, Stanislaus County, March 1943. Note massive cherts in thin-bedded cherts and shales. The ore occurs in the massive cherts. *Photograph by Theo H. Crook.*





Fig. 10. Massive bed of gray manganese carbonate, cut by many veins of rose-red rhodochrosite, interbedded with crumpled thin-bedded red radiolarian chert and shale. The hammer at the lower contact of the ore is 15 inches in length. Southwest face of Impassible Rock, Sanhedrin Ridge, Eden Valley quadrangle, Mendocino County. Since the face of Impassible Rock is an almost vertical cliff the surface of the manganese carbonate lens shows only a film of black manganese oxide.



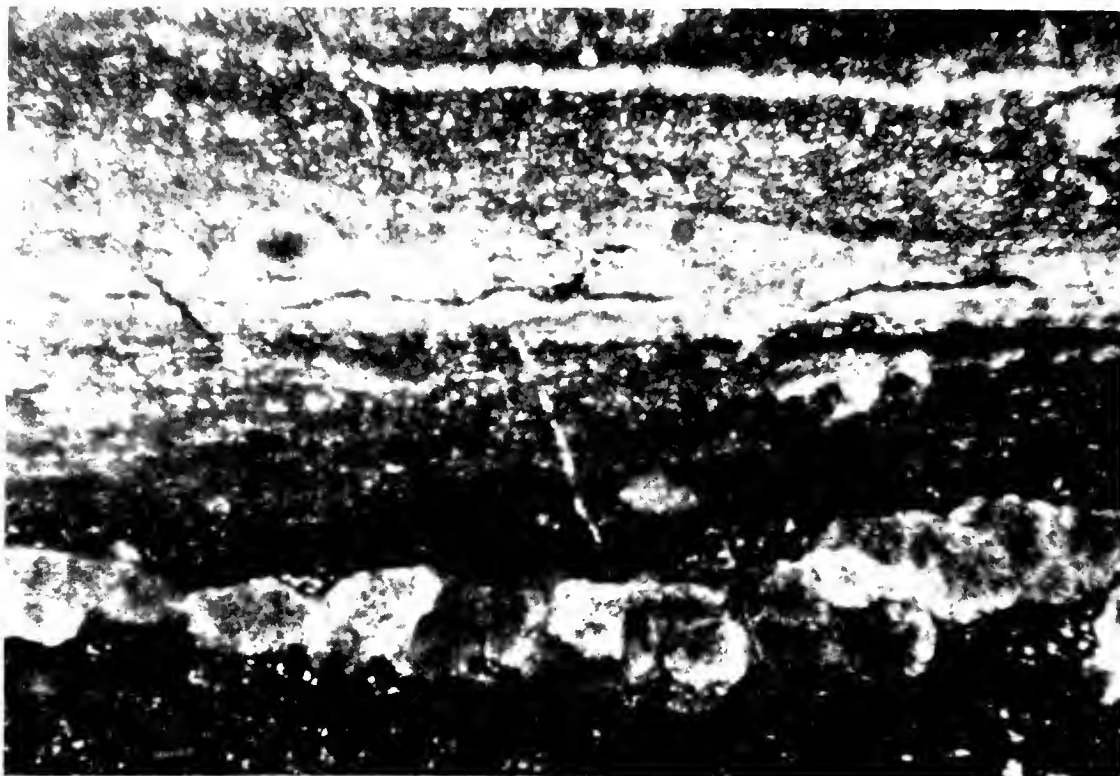
Fig. 11. Termination of the manganese carbonate lens shown in figure 10. Note blunt wedge-shaped termination of the massive lens and the numerous veins of rose-red rhodochrosite cutting the carbonate ore. Southwest face of Impassible Rock.



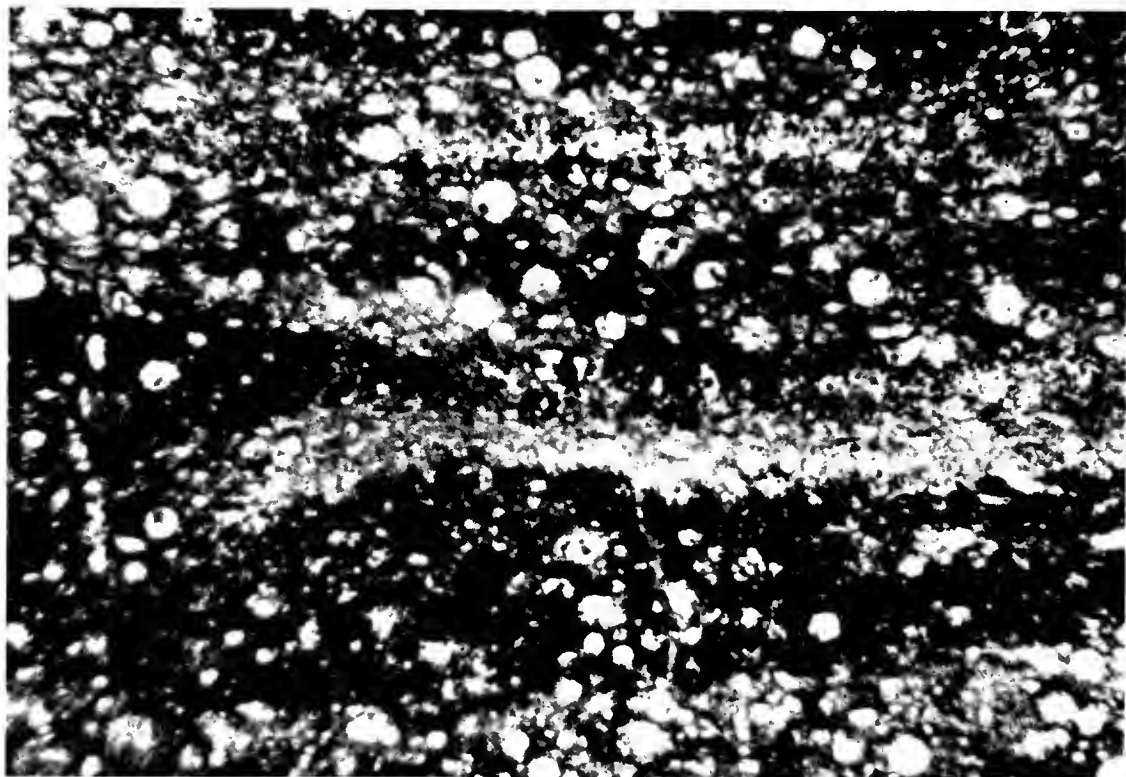
Fig. 12. Photomicrograph (x21). Slightly recrystallized original ore that gives rise to rather high-grade black oxide ore. Spherules of manganese carbonate embedded in a partially recrystallized manganiferous opal. The products of recrystallization are fibrous hydrous manganese silicates, some of which may be of the bementite type. Cut by veinlets of rhodochrosite. Buckeye mine, Carbona quadrangle, Stanislaus County.



Fig. 13. Photomicrograph (x21). Same as above, but with crossed nicols showing characteristic polarization crosses in the spherulites.



**Fig. 14.** Photomicrograph (x21). Lens formed by coalescence of spherules of manganese carbonate in streaky, partly recrystallized manganiferous opal. Buckeye mine, Carbona quadrangle, Stanislaus County.



**Fig. 15.** Photomicrograph (x21). Manganiferous red radiolarian chert, Redrock Canyon, Santa Ynez quadrangle, Santa Barbara County. The dark lenses are black, opaque manganese oxides developed from manganiferous chert; the light bands are of chalcedonic chert stained with iron oxide but practically free from manganese.



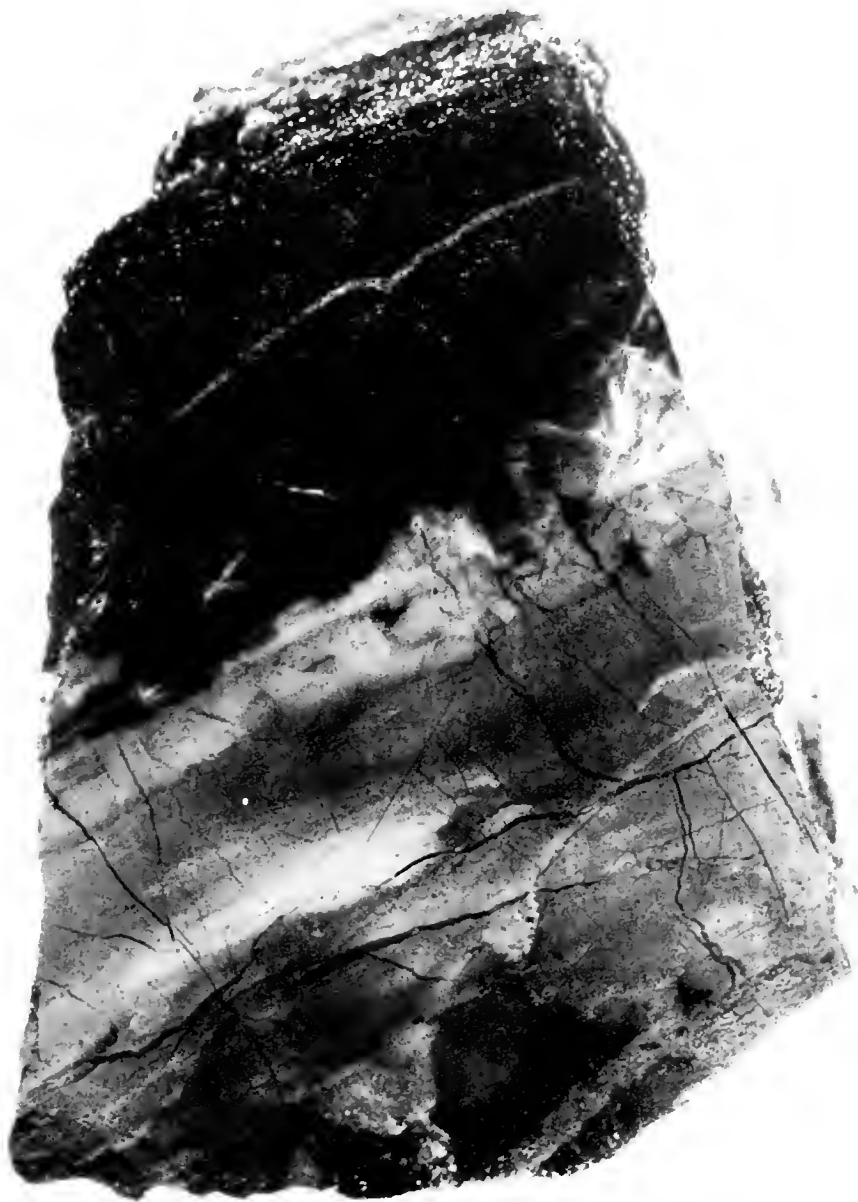
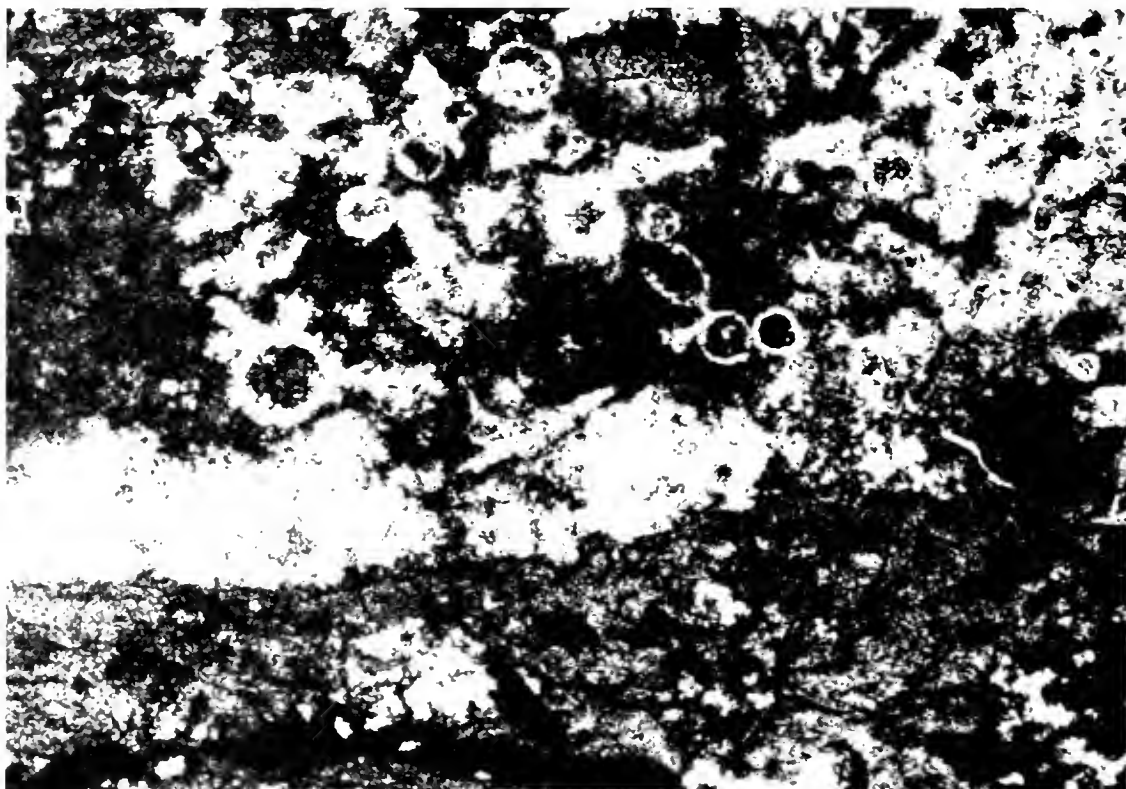


Fig. 16. Polished surface of original manganiferous opal passing into a surface coating of siliceous black manganese oxide ore. Natural size. Woods mine, Humboldt County. Note lens-like nature of the original ore shown by variations in color that reflect the amount of manganese present in the opal. Cut by veinlets of chalcedony and various yellow, orange, and brown hydrous manganese silicates. This material gives rise to a siliceous black manganese oxide ore. For photomicrographs of this material see figures 20, 21, and 22.



**Fig. 17.** Photomicrograph (x55). Radiolaria in spherulitic manganese carbonate and dark-brown, completely isotropic manganiferous opal. The Radiolaria are replaced by manganese carbonate. Red Cliff prospect, Hulls Creek, Covelo quadrangle, southern Trinity County.



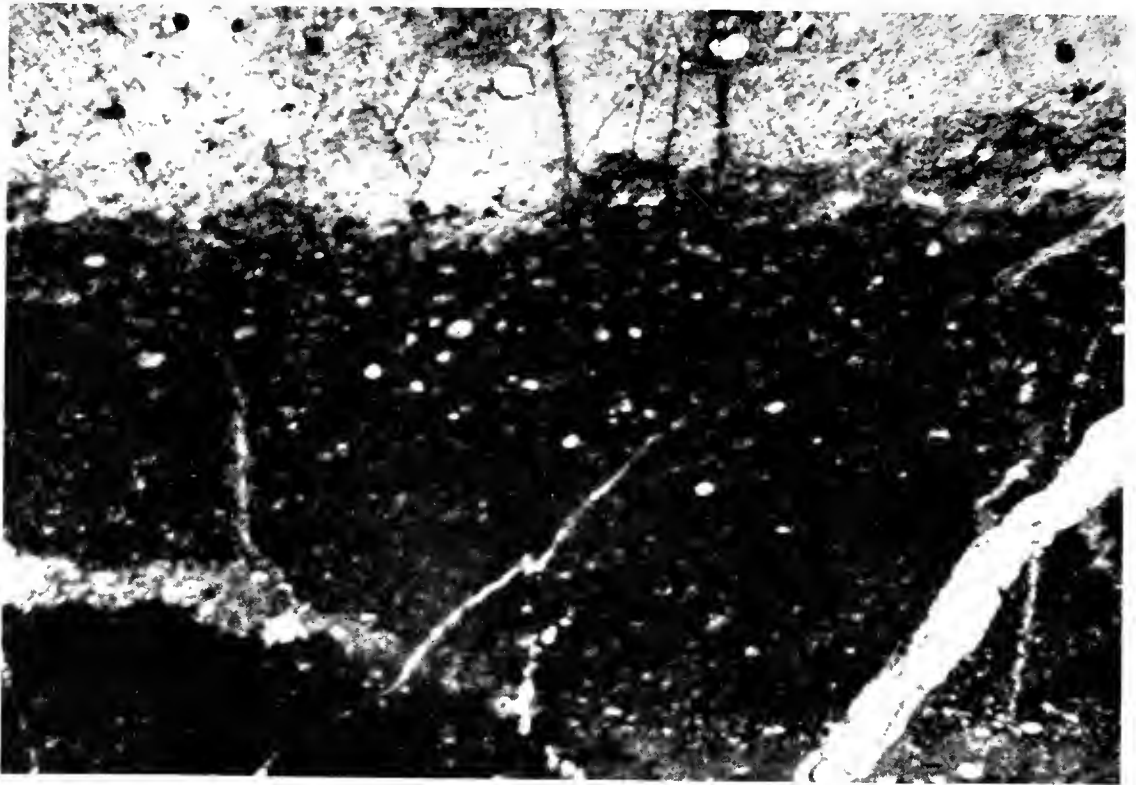
**Fig. 18.** Photomicrograph (x53). Radiolaria in isotropic yellow-brown manganiferous opal. Small veinlets of rhodochrosite and yellow to orange-colored hydrous manganese silicates. Some of the Radiolaria are partially or wholly replaced by manganiferous opal.



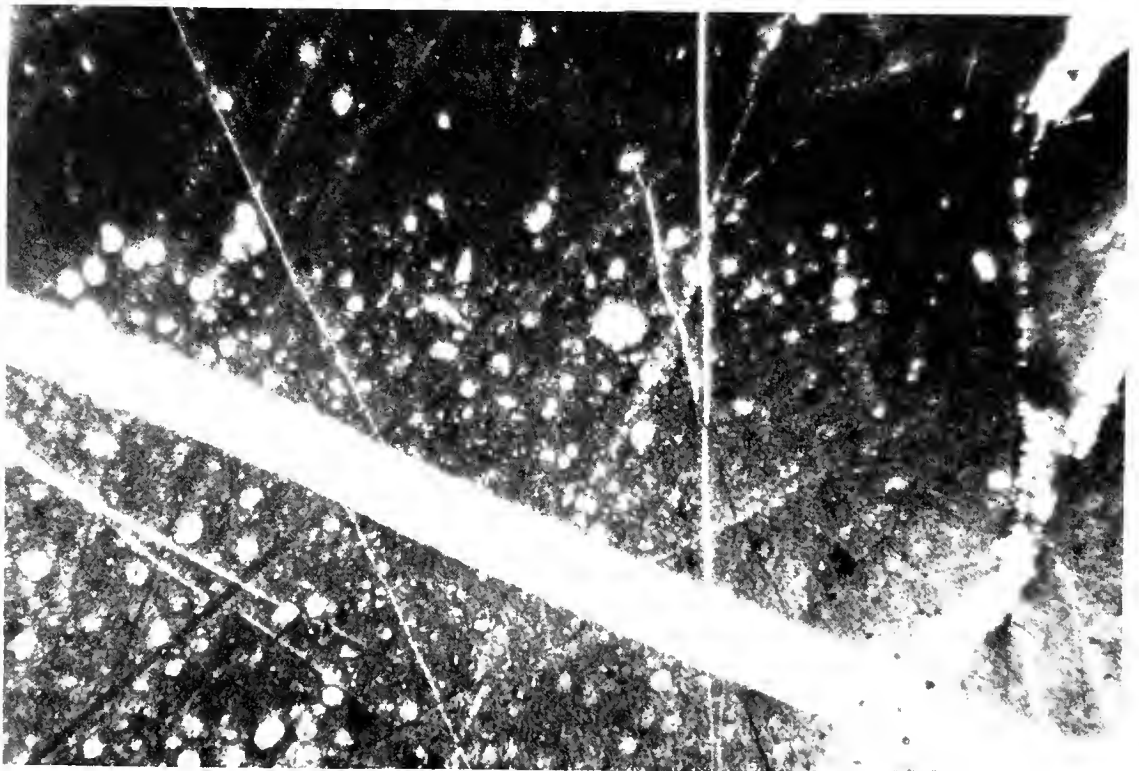
**Fig. 19.** Photomicrograph (x53). Unreplaced Radiolaria in brown, slightly oxidized, manganiferous opal and chert. The lower dark part is fairly high (over 35 percent) in manganous oxide. The light band is very pale yellow chert. This material gives rise to a siliceous black oxide ore. See figure for polished surface of original ore passing into black manganese oxide ore.



**Fig. 20.** Photomicrograph (x53). Partially replaced Radiolaria in almost completely amorphous brown manganiferous opal. Small veinlets of rhodochrosite and yellow-brown hydrous manganese silicates. Spherulitic manganese carbonate in upper lefthand corner. This material oxidizes to a rather high-grade black oxide ore averaging 45 percent Mn. Woods mine, Humboldt County.



**Fig. 21.** Photomicrograph (x21). Abundant Radiolaria in isotropic manganiferous opal. The light band in the upper part is almost colorless and is simply a slightly manganiferous chert. The veins are of quartz and yellow-brown hydrous manganese silicates. This original material oxidizes to a siliceous black oxide ore containing up to 40 percent Mn. Woods mine, Humboldt County.



**Fig. 22.** Photomicrograph (x21). Pale brown isotropic manganiferous opal with abundant, wholly unreplaced Radiolaria. The color is dependent on the amount of manganese in the opal. This original ore gives rise to fairly high-grade black oxide ore containing about 45 to 47 percent Mn. The veins are quartz. Woods mine, Humboldt County.



but there are many showing no sign of replacement. Color banding, indicating a variable manganese content, is conspicuous in some slides. The refractive index of the brown manganiferous opal, as determined in the usual manner using crushed material in oils, shows a range from slightly less than 1.5 to 1.60, the darker material having the higher index. The specific gravity also varies from 2.51 to 2.95. The specific gravity is not entirely a function of the variation of manganese content in the manganiferous opal but is, in part, dependent on the amount of carbonate present as shown by the following table:

*Specific gravities of various types of original manganese ores from the Woods mine, Humboldt County*

No.	1	2	3	4	5
Sp. Gr.	2.51	2.63	2.84	2.89	3.09
No. 1	Resinous light brown manganiferous opal free from black oxide or carbonate.				
No. 2	Dark brown resinous manganiferous opal.				
No. 3	Brown manganiferous opal containing 10 to 15 percent carbonate.				
No. 4	Dull brown material containing some carbonate. Average of 3 determinations made by A. Pabst with the Berman balance.				
No. 5	Dull brown carbonate-opal mixture with a greater amount of manganese carbonate than No. 4.				

Because of the small size of the bands and lenses it has been impossible to separate the different kinds of material so that the indices and specific gravities could be exactly related to each other and to the shades of color but, when the analyses that will be given later are considered, it is clear that the index and gravity both increase with the amount of manganese and that there is a roughly corresponding increase in depth of color.

Several analyses of this material have been made. These are given in the following table:

*Analyses of original ore from the Woods mine, Humboldt County*

	1	2	3
SiO <sub>2</sub> -----	29.90	33.65	36.4
Al <sub>2</sub> O <sub>3</sub> -----	1.50	1.70	2.9
Fe <sub>2</sub> O <sub>3</sub> -----	1.35	1.46	
FeO -----	Trace	Trace	Trace
MnO -----	48.70	40.22	37.2
CaO -----	.90	1.10	1.8
MgO -----	1.98	1.77	2.2
K <sub>2</sub> O and Na <sub>2</sub> O -----	Trace	Trace	n.d.
H <sub>2</sub> O— -----	2.00	7.20	4.4
H <sub>2</sub> O+ -----	8.50	7.30	8.1
CO <sub>2</sub> -----	5.05	5.50	4.9
P <sub>2</sub> O <sub>5</sub> -----	.06	Trace	n.d.
BaO -----	Nil	Nil	n.d.
	<hr/> 99.94	<hr/> 99.90	<hr/> 97.9

1. Dark dull brown ore, contains some carbonate. Analysis by Herdsman, Glasgow. Sp. gr. 2.89.
2. Glossy very dark brown opaline ore. Analysis by Herdsman, Glasgow.
3. Resinous brown opaline ore. Analysis by N. L. Taliaferro.

All of the material analysed contains more or less manganese carbonate and a few thin veins of the pale yellow to orange-brown birefringent minerals previously mentioned as occurring in the carbonate. However, in the three analyses  $\text{CO}_2$  is fairly constant while there is considerable variation in the manganese oxide and silica, the manganese rising as the silica decreases. This, together with the observations made with the microscope indicates that neither the manganese oxide nor the silica is present in definite proportions. Observations on similar material from other localities indicate that there is an even greater range in the proportions of silica and manganese oxide.

A number of pieces of the resinous brown ore were treated with hydrochloric acid of varying concentration. Even in dilute acid all of the manganese is removed in a few days from pieces up to three-quarters of an inch in diameter, leaving a coherent, though friable piece of opal of the same size. If a small fragment about a quarter of an inch in diameter is leached with very dilute acid the fragment will not disintegrate but will leave a spongy piece of opal of the same size and shape. This experiment was repeated five times on the material from the Woods mine and a number of times on material from other localities with the same result. The opaline residue from the Woods mine was dried and examined under the microscope and found to consist of amorphous opal with the same hazy, ill-defined areas of very weak birefringence as in the original brown manganiferous opal. The index of the opal is constant in all of the material examined, being  $1.449 \pm .0003$ . The oils were repeatedly checked on a refractometer.

The water content of the opaline residue was determined and found to be 14 percent, which is the same as in the original, unleached manganiferous opal. Thus all of the water appears to be locked in the structure of the opal; the manganese is present as manganous oxide and not in a hydrated form. The manganese oxide appears to have been included in the structure of the silica gel as it formed; just as silica gel will absorb and include other substances either in solution or in the colloidal form.

The writers consider that they have sufficient evidence to state that the original brown resinous material is essentially made up of manganous oxide, silica, and water, in varying proportions. The formula for this variable manganiferous opal could be written:  $x \text{ MnO} \cdot y \text{ SiO}_2 \cdot z \text{ H}_2\text{O}$ .

If it is necessary to give a mineral name to the substance the best that could be given would be *neotocite*. From an examination of the literature it is found that the composition, index, and specific gravity of neotocite are extremely variable, corresponding to the manganiferous opal just described. The index, as given, varies from  $1.47 \pm$  to  $1.54 \pm$  and the specific gravity from 2.5 to 2.7. However, neotocite always has been described as an alteration of rhodonite, which the syngenetic radiolarian manganiferous opal just described is not. The writers have found veinlets of secondary neotocite in the Sierra Nevada clearly derived from rhodonite but the field relations of the Sierran neotocite are vastly different from those of the manganiferous opal of the Coast Ranges.

For those who must give a specific mineral name to the substance just described the name neotocite would be the most suitable. However, the writers regard the material more as a rock than as a specific mineral. It grades into radiolarian chert and has the same geologic mode of occurrence and it is an original chemical sediment just as is chert, although not

nearly as common. They believe that the pure material should be referred to as manganiferous opal.\*

A careful microscopic examination of more than 20 thin sections of this material shows that none of the minerals, other than manganese carbonate (rhodochrosite) listed as possible are present. (Manganosite, hausmannite, dolomite, alleghanyite, and tephrotite are not present.) The only substances present are the manganiferous opal previously described, spherules of manganese carbonate up to 10 or 15 percent, and a few veinlets of yellow to brown hydrous manganese silicates. These occur in minute, weakly to strongly birefringent needles that have not yet been identified. Some of them may be bementite or a mineral of this general type. These vein minerals undoubtedly account for the lines that can not be ascribed to manganese carbonate. Unfortunately there is no X-ray pattern of bementite available for comparison at present.

Brown opaline ores are very widely distributed throughout the Coast Ranges and the description just given would be applicable to practically all unaltered deposits of this type. The altered products and the various types of alteration will be briefly described in a later section.

The degree of recrystallization of the cherts and the associated ores do not always exactly correspond. As a rule the less recrystallized the chert the less altered is the ore but practically unaltered manganiferous opal-spherulitic carbonate ores have been found inclosed in thin-bedded cherts that have recrystallized to a very fine-grained mosaic of chalcedony. From this observation it would appear that the ores do not crystallize quite as readily as the opaline silica of the chert. The ores are certainly softer and it is possible that they are slightly more plastic than the cherts. There also is more water remaining in the manganiferous opal than in the cherts with which they are associated.

Usually the ores are mixtures of manganiferous opal and carbonate in varying proportions, which are far from constant even in the same lens. Where alteration and crystallization have not modified or obliterated the relationships the manganese carbonate occurs as spherules, varying in size from those scarcely visible under the microscope to those approximately one millimeter in diameter. These may occur scattered at random throughout the brown manganiferous opal or arranged in trains along the same horizon. Small lenses, seen under the microscope, are formed by the coalescence of spherules and some of the larger lenses may be formed in the same manner. This, as well as color variations in the opal, gives rise to banded ores. However, not all of the ores are banded as the two original materials may be very irregularly dispersed, one through the other. (See figures 12, 13, and 14.)

#### Radiolaria in the Original Ores

Radiolaria are moderately abundant in many of the unaltered ores, either manganese carbonate or manganiferous opal, but only rarely are they as abundant as in the thin-bedded cherts. However, Radiolaria

\* X-ray examination of the brown opaline ore shows that it contains a considerable proportion of rhodochrosite, manganese carbonate. No other manganese minerals could be certainly identified, though it is possible that some are present in minor amount. Quartz and other crystalline forms of silica as well as manganite, pyrolusite and cryptomelane are not present in sufficient amount to be recorded in the X-ray pattern. This still leaves the possibility that a major part of the ore consists of one or more unidentified manganese minerals. *Personal communication from Adolf Pabst, June 23, 1943.*

are rarely as abundant in the massive cherts with which the deposits are associated, as they are in the thin-bedded cherts that inclose both the massive cherts and ores. The preservation of the Radiolaria varies just as it does in the cherts. Some are so well preserved that the spines and some of the details of the structure of the walls may be seen. The best preserved Radiolaria are found in the Red Cliff prospect in Trinity County. This small prospect, which is not sufficiently large or deeply enough oxidized to justify exploitation occurs near the base of a cliff of red chert on the east bank of Hulls Creek, about half a mile north of the mouth of Casoose Creek.<sup>16</sup> It is located in southern Trinity County, just north of the Mendocino County line, in the NE.  $\frac{1}{4}$  Sec. 36, T. 5 S., R. 8 E., H. The deposit is a lens in massive chert interbedded with thin-bedded red radiolarian chert and shale that dip rather gently northeast. The chert is so little altered that it is still partly opaline and the ore is completely unaltered and cut by comparatively few veins. Because of its position on a cliff there are only thin surface films of black oxide. The ore is liver brown, often has a dull pearly luster. Minute veins of rhodochrosite occur. Under the microscope it is seen to be made up of spherulitic manganese carbonate and yellow to brown, entirely amorphous, manganiferous opal. These usually are irregularly intermixed, although bands of each occur in which only a small amount of the other is present. There are a few very small areas of cloudy red iron oxide. The bands and irregular patches of manganese carbonate are made up of small to large (1 mm), ill-defined and mutually interfering spherules. There are a few fairly well-defined rhombs but even these show spherulitic structure. Radiolaria are abundant in the six thin sections that have been examined. They occur both in the carbonate and brown opal but are most numerous in the former. Although they have been largely replaced by manganese carbonate they are unusually well preserved as are a few sponge spicules that are present. Rather a large variety of forms is present; both of the suborders *Spumellaria* and *Nasselaria* are represented. Figure 17 is a photomicrograph of this mixed ore.

Very commonly the Radiolaria are replaced by either manganiferous opal or carbonate; but many, particularly those in the brown opal, are only partially replaced, or not replaced at all. This is not regarded as evidence for a replacement origin of the ores. It would be expected that the delicate opaline tests of the Radiolaria that became entombed in the manganiferous deposits, probably originally soft oozes like the cherts, would be replaced. In fact most of the radiolarian tests found in Franciscan limestones have been replaced by calcium carbonate. The senior author has collected Franciscan-Knoxville radiolarian shales from a number of localities in the Coast Ranges and in these the Radiolaria are invariably replaced by calcium carbonate.

The writers have no intention of giving the impression that radiolarian remains are common in most of the deposits. They are not, as so many of the deposits have been altered in some way. They are present, however, in practically all unaltered or little-altered ores. They even have been found in oxidized manganiferous bands in cherts. The occurrence of Radiolaria in the ores is illustrated in the accompanying figures 15, 17, 18, 19, 20, 21, and 22.

<sup>16</sup> The name "Casoose Creek" appears on both the Forest Map and the Covello quadrangle of the U. S. Geological Survey. Its derivation is somewhat curious and deserves a note. The creek was named from an old Mexican who lived on the creek for many years, and whose name was Jesus, a common Spanish name. Obviously Casoose is a corruption of Jesus.

## Form and Association of the Orebodies

The vast majority of the orebodies occur within or in close association with chert lenses of greater thickness than the usual thin-bedded cherts. These more massive cherts with which the orebodies are associated are characterized by an absence of shale partings and hence are massive. There is wide variation, however, in the relationships of ore, massive chert, and thin-bedded chert. In some instances the ore lens plays the same role as a massive chert and we find a massive lens of ore entirely inclosed in thin-bedded chert. The ore may occur as a single massive lens or as several lenses along the same stratigraphic horizon. In other, and more numerous, cases the ore lenses may be within the massive chert. The many possible variants are briefly outlined in the following table.

*Mode of occurrence of orebodies*

- I. Lenses of ore inclosed in thin-bedded cherts and shales.
  - A. Massive ore lenses inclosed in thin-bedded cherts and shales and playing the same role as massive chert.
  - B. Layers and lenses of ore associated with a massive chert, the whole being inclosed in thin-bedded chert and shale.
    1. Ore at top of massive bed.
    2. Ore at bottom of massive bed.
    3. Ore in midst of massive bed.
    4. Ore at one side of massive bed but stratigraphic position indeterminate.
  - C. Massive bed of ore, or of ore in massive chert, resting on sandstone but overlain by thin-bedded cherts and shales.
  - D. Massive bed of ore, or of ore in massive chert, resting on basalt and overlain by thin-bedded chert and shale.
  - E. Lenses of ore immediately adjacent to a massive chert bed but separated from it by a thin parting of shale.
- II. 1. Lenses of ore imbedded in red shales of the same type as those occurring between the cherts with a few thin lenses of chert (but one example).
  2. Thin ore lenses, comparable in thickness with the thin-bedded cherts with which they are associated, and separated by thin partings of red and green shale, the whole being inclosed in an ordinary chert-shale lens (rare).
- III. Replacements of limestone on the border of intrusive greenstone (but one example).

Subdivisions C, D, and E are merely accidental variants of either A or B. II simply indicates that, very exceptionally, the amount of manganese locally may have greatly exceeded the amount of silica. III is a special case that will be described later.

In addition there are occurrences that are obviously accidental and having no genetic significance, such as loose blocks in the soil and sheared and crushed lenses along strong fault zones.

The massive lenses of ore inclosed in thin-bedded cherts and shales may be either of carbonate or manganiferous opal or, more commonly, of the mixed type. Such lenses are entirely analogous to the massive chert layers previously described and simply indicate that, locally, there was an unusually large amount of manganese present. They have the same general form and modes of termination as the massive chert lenses. They may have either blunt wedge-shaped or gradually tapering edges. (See figures 10 and 11.) None has been observed to terminate by the appearance of shale partings on the edges. Lenses of this character are sharply separated from the thin-bedded chert and shale in which they are inclosed, and there are no gradations along the margins. However, when oxidized there is, frequently, a tendency for the black oxides to migrate into the inclosing cherts along joints and to leave the usual black film.

Massive beds of ore may be inclosed either in thin-bedded chert with only thin film-like shale partings or in those in which the shale partings are of appreciable thickness. They also may occur in cherts of any color. However, they are most common in thin-bedded red radiolarian cherts since these are the predominant type. However, lenses of ore are found in green and in mixed green and red cherts. In other words, there does not appear to be any relation between the occurrences of massive ore, or of the massive chert with which the ore is associated, and the type of larger chert-shale lens. The only possible relation between color and the occurrence of ore is the fact that the massive cherts are, as a rule, somewhat paler in color than the inclosing cherts.

In places the ore lens is separated from the inclosing chert by a shale parting of the same thickness as that prevailing in thin-bedded chert lens, but in other places the massive lens may be in direct contact with a thin-bedded chert with only a film of shale. Both massive cherts and massive ore lenses appear as minor interruptions in the depositional history of the chert-shale lens in which they are inclosed and may appear anywhere within the larger lens. Fundamentally they may be regarded as a thicker variety of the ordinary chert making up the lens, the chief difference being the absence of shale partings in the massive bed. If the supply of detrital material was constant during the formation of the entire chert-shale lens then the massive beds, either of chert or ore, would be the result of the more rapid addition, either of silica or of manganese, or of a more rapid flocculation of the colloidal material. In other words the chert-shale proportions and relations and the usual manner in which the thin-bedded cherts and shales wrap about the end of a massive bed indicate that the time required for the formation of a massive bed was not appreciably greater than the time of formation of a thin bed. The writers are of the opinion that the massive beds, either of chert or ore, are the result of more rapid local addition of silica and/or manganese or its more rapid flocculation. There is nothing in the relations that have been described to indicate that fine detrital material was present in lesser amounts in the oozes during the formation of a massive lens than during the formation of the usual thin-bedded cherts and shales.

A more common occurrence of ore is as lenses within or on the margins of a massive bed, inclosed as usual in a thin-bedded chert-shale lens. These may occur at top, bottom, or within the massive chert lens, and may be single and co-extensive with the massive chert, or repeated several times along the same horizon. They appear to occur at the top of the massive chert more frequently than at the bottom. Lenses within massive cherts range in thickness from a millimeter to several feet and may be of carbonate, manganiferous opal, or a mixed type. Usually the boundaries against the massive chert are sharp, except in the case of carbonate lenses that develop by the coalescence of trains of spherules. Even here the contact is, essentially, sharp as each spherule, or a lens made up of an aggregation of spherules, is sharply bounded.

The only instance, known to the writers, of ore lenses in shale is at the Fort Baker mine in Humboldt County, but this is only an apparent exception to the rule, as the red shale is of the same type as that between lenses of red chert. At this mine the ore occurs as small lenses within a thick bed of soft red shale which is, in turn, inclosed in thin-bedded red radiolarian cherts. The ore is largely oxidized but appears to have originated from a mixed carbonate-manganiferous opal type. The ore lenses

lie with their longer axes parallel to the bedding of the cherts and shale, and occur at different horizons within the shale. Occasionally ordinary red chert lenses have exactly the same mode of occurrence and appear as small nodular lenses within an unusually thick body of red shale.

Rarely the ore occurs as thin lenses comparable in thickness with the ordinary thin-bedded cherts. The ore lenses usually occur in a zone 2 or 3 feet thick and are separated from one another by red shale, just as thin lenses of radiolarian chert are separated by shale. The lenses of ore are parallel to the layers of the inclosing chert and shale and at a short distance are indistinguishable from the cherts, except for color.

The ore lenses, or more properly the manganese-bearing lenses, show almost all possible variations in manganese content from those of practically pure manganese carbonate to those which only contain a sufficient amount of either carbonate or brown opal to yield a light film of black oxide. There are many massive chert lenses that can not be called ore but which are strongly stained and filmed with black oxide, the result of the oxidation of scattered spherules of carbonate or small lenses of brown opal.

When undisturbed by shearing and faulting the ore lenses are seen to have the same mode of occurrence as the cherts with which they are associated except that they are nearly always associated with the more massive cherts. The ore lenses have the same form and terminate in the same way as the chert lenses. They are veined in the same manner (but not necessarily with the same minerals) as the cherts and, as with the cherts, the veins increase in size and number with increasing deformation and alteration. Even when strongly deformed the orebodies behave in the same manner as the cherts with which they are associated.

#### Exceptional Occurrences

The only noteworthy exception to the modes of occurrence just outlined has been reported by Dr. Parker D. Trask of the United States Geological Survey. The occurrence has not been visited by the writers and the following brief description is based on a personal communication from Dr. Trask.

North of Shelter Cove, in Mendocino County, on Usal Creek not far east of the coast, there are several small deposits that are unique in that they are not associated with chert and are not syngenetic but are replacement deposits. Here there are lenses of limestone, usually resting on altered basalt flows and cut by intrusive "greenstone." (Greenstone is a name commonly applied to altered basalts and diabases. It is of the same general nature as the flows in the Franciscan and, in places, the intrusive bodies are the feeders for flows.)

The limestone has been replaced by iron and manganese for a distance of a few feet from the intrusive contacts. The form in which the manganese occurs is not known to the writers. The deposits are said to have little economic value.

#### Variation in Composition Within an Ore Lens

An individual orebody may be homogeneous, or nearly so, throughout its extent, but this is the exception rather than the general rule. Usually the internal variation is complex and the nature and quality of the ore may change from place to place even in a small lens. The lenses



nearly always are banded, the banding being the result of numerous lens-like areas that are essentially parallel to the bedding of the larger lens and the surrounding cherts. The small lens-like areas consist of different types of ore, or of the same type ore with varying proportions of silica or, in some instances, of iron. Sometimes the contacts between the different materials are sharp, but just as often they are gradational.

The sharpest contacts occur between carbonate spherules and lenses and manganiferous opal. In one sense even these contacts are at times gradational, as a lens of carbonate may form as the result of an increase in abundance of the spherules. Lenses of almost pure manganiferous opal vary, as has been previously described, from those that are pale yellow brown and low in manganous oxide to those that are dark brown and high in manganese. A similar type of variation occurs in individual lenses of the ordinary cherts where there are marked variations in color caused by differences in the iron content. There also may be great differences in the abundance of Radiolaria in a single chert lens, some layers being crowded with remains while others are practically barren.

This variation in the original type of material is reflected in the oxide ores formed from a particular lens. In one place there may be high-grade shipping ore, while in another place the material may require hand sorting before shipment, or be of little or no value because of the high silica content.

#### Relation of Orebodies to the Structure of the Inclosing Rocks

As previously stated the orebodies, when undisturbed by strong faulting, are everywhere parallel to the inclosing cherts, and the individual ore lenses differ in no way in outward form from ordinary chert lenses. The ore lenses exhibit the same general structural features as the rocks with which they are interbedded, behaving in this respect as any normal sediment. They follow both the major and minor bends and are offset by transverse faults just as are the inclosing cherts. Well-exposed cliff sections have been observed in which the ores followed all the minor contortions of the cherts. The same phenomenon has been seen in mines and prospects. Plunging folds in the Franciscan have been mapped and the ore lenses are found to exactly parallel the bedding and to plunge with the sediments and volcanics involved in the folding.

In the case of large folds lenses of commercial ore on one limb may be too low grade to be economic, or even may be missing on the other limb. However, this is equally true of even large chert bodies which may lens out from one limb to another. This is well illustrated by the manganese deposits in the northwestern corner of Stanislaus County, of which the Buekeye mine is the largest. (See figure 9.) These deposits occur on the northern limb of the large Mount Oso anticline which passes through Mount Oso. On the northern limb there are many chert lenses, a number of mines, and several horizons of commercial ore; but on the southern limb, at an equivalent stratigraphic horizon approximately 3 miles to the south, there are fewer chert lenses in the sandstones, much less staining and filming by black manganese oxide, and only a few low-grade manganiferous lenses.

In the two largest manganese mines in California, as far as past production and extent of the underground workings are concerned, the orebodies, as exposed both on the surface and underground, are seen to follow all contortions of the inclosing beds.



## Relation of the Chert and Manganese Ores to Basic Lavas

Basic lavas are of such widespread occurrence in the Franciscan that they can be considered an essential part of the group. Many geologists familiar with the Franciscan have expressed the idea that the cherts are genetically related to the lavas. The physical relations of the manganese ores to the enclosing cherts seem to preclude the possibility that ores were deposited in any other way than syngenetically with the cherts and this leads directly to the idea that the ores and lavas are genetically related. In the following paragraphs what appears to be corroborative evidence of this relationship is given.

Basalts, diabases, and gabbros in general are richer in manganese than other igneous rocks. In his *Data of Geochemistry*, Clarke gives 0.10 percent MnO as the average manganese content of the igneous rocks of North America. An examination of complete analyses of various types of igneous rocks shows that there is a general increase of manganese content from rhyolites and granites at the low end of the series, through andesites to a maximum in the basalts and gabbros, beyond which there is a decline, so that the peridotites and pyroxenites carry only about as much as andesites and diorites. Rhyolites, dacites, granites, and quartz diorites contain generally much less than 0.10 percent MnO, namely, about 0.07 percent. Although there are many cases in which appreciably more than 0.10 percent MnO is reported, there are about the same number of cases in which careful analysis failed to find any manganese. Basalts, gabbros, and diabases contain an average of about 0.25 percent MnO, with almost all analyses showing more than 0.10 percent, and very few reports of no MnO.

The weathered outcrops of Franciscan basalts and diabases are stained by thin blue-black films of manganese and iron oxides almost as frequently as are the Franciscan chert outcrops, and it is the authors' impression that this staining is in greater quantity and extent than is to be seen in the general run of other igneous rocks of the Coast Ranges. Unfortunately, complete analyses of Franciscan basalts are not available to confirm the idea that they are rich in manganese, but the occurrences of peculiar iron-manganese-opal ores in the basalts, that appear to be of syngenetic origin, are confirmatory of the idea.

The following discussion of these ores is from an unpublished manuscript prepared by Dr. E. F. Davis in 1918:

"There are in this region [northern Coast Ranges] certain remarkable iron ores that are intimately associated with Franciscan greenstones and pillow basalts. These iron ores invariably contain small amounts of manganese. Deposits of this character are especially common in the southern part of Lake County and the northern part of Napa County, though they are found all through the northern Coast Ranges.

"These ores occur as lenses enclosed in Franciscan greenstone but the relations of the orebodies to the enclosing greenstone are not always as clear as the deposits have not been opened to any extent by mining operations.

"At the Adams prospect north of Monticello a deposit of manganiferous iron ore has been exposed in such a way that its relations to the surrounding rocks are clearly seen. The orebody is seen to be a thick lenticular bed enclosed in beds of tuffaceous greenstone intercalated with massive lavas.

"The character of these iron ores varies somewhat. Sometimes a deposit consists almost entirely of one of the varieties mentioned below, but generally the deposits contain several varieties of material.

"Some of the deposits contain considerable amounts of soft, red hematite. This material is rendered silicious by the presence of bands and streaks of red, or brown chert. Much of the material in these deposits might be called opaline iron ore, as it consists of an intimate mixture of opal and ferric iron oxide.

"This material breaks with a smooth conchoidal fracture, has a hardness of about four, and is very brittle. It possesses a bright waxy to almost resinous luster. The color varies somewhat with changes in the content of manganese. The most common variety is liver brown in color, but with decreasing content of manganese it passes

through reddish brown to brick red. Rarely a bright cherry red is seen in varieties containing no manganese.

"Small amounts of a greenish opaline material are found in some of the deposits. This appears to be colored by ferrous iron, since it undergoes oxidation at the surface. Cores and patches of white to pale yellowish porous silica are found in the oxidized portions of this material. These greatly resemble the porous silica found where brown manganese ores have oxidized. Small streaks of specular hematite have been found with these opaline iron ores.

"These ores contain varying amounts of manganese, and their weathered outcrops are generally heavily stained with black manganese oxide, so that they form rather conspicuous outcrops. Analyses of numerous specimens show that their content of metallic manganese ranges from less than a percent up to 12 percent; 7 to 8 percent is a common figure for manganese in these ores. Ferric oxide ranges up to 60 percent; silica is generally 20 percent or 30 percent, but may approach 40 percent.

"While the typical occurrences of this opaline iron ore are distinctly different from those of the ordinary manganese ores, there are certain facts that suggest a relation between these two types of ore. The manganese in some of these opaline iron ores was originally in the form of disseminated spherules of manganese carbonate. In other places there are minute streaks of 'brown ore' scattered through the opaline ore. In some of the deposits of manganese ore there are small lenses and bands of opaline iron ore interlayered with lenses of brown manganese ore or brown carbonate. In some of the deposits of iron ore there are bands and lenses of radiolarian chert.

"At the Herndon prospect east of Lower Lake opaline iron ore is found enclosed in radiolarian chert, and is separated from greenstone by several feet of ordinary red radiolarian chert. Here also the opaline iron ore may at times play the same role as the ordinary red shale and form the partings between thin layers of radiolarian chert.

"The manganiferous opaline iron ores are probably without commercial value. They are too high in silica to be useful as iron ores and the manganese content is low. Mechanical concentration does not appear practicable, and the chemical separation of manganese from the large amounts of iron should present difficulties."

There are other high-iron, low-manganese deposits that occur interbedded with cherts in exactly the same manner as the manganese deposits. However, a detailed study has not been made of such ores and little can be said regarding them except that the resinous brown iron-manganese substance is, when unaltered, amorphous, and is a ferruginous manganiferous opal similar, except for the high iron content, to the manganiferous opal previously described. The iron carbonate is occasionally present.

The deposits of the type described by Dr. Davis indicate a definite genetic relation between the iron manganese ores, cherts, and basic volcanics. The usual close association, both in time and space, of the cherts, lavas, and manganese and iron ores is also regarded as evidence of a genetic relationship.

#### Alteration of the Original Ores

The original ores, and the inclosing cherts, have experienced all of the disturbances experienced by the Franciscan in general. Since these disturbances have been described in an earlier section they will not be discussed again except to state that the Franciscan, and all its component parts, including the ores, has been folded and faulted a number of times, intruded by contemporaneous as well as later intrusions (minor intrusions, not batholiths), and parts have been buried beneath a great thickness of Cretaceous and Tertiary sediments. Because of this long and complex history the ores, as well as other rocks of the Franciscan, have been altered to varying degrees and in several ways.

Three main types of alteration may be recognized:

First, simple recrystallization to varying degrees, caused by folding and the weight of superincumbent beds (weak dynamic and static metamorphism).

Second, pneumatolytic contact action on the margins of basic and ultrabasic intrusives.

Third, hydrothermal alteration of various probably complex types.

The second and third types are local and have been superimposed on the first.

Simple recrystallization has commonly taken place but it has varied greatly, as shown by practically all the rocks but particularly by the shales and cherts. In some places Franciscan-Knoxville shales are practically unaltered while in others, where they have been deeply buried or strongly folded, they are somewhat slaty. The cherts are in some places still opaline, but in other places they have crystallized to a fine mosaic of chalcedony or quartz. The manganese ores exhibit the same variation, some being practically unaltered, others showing strong recrystallization. Also, as in the case of the cherts, the greater the deformation the more numerous the veins in the ores.

Recrystallization of the original spherulitic manganese carbonate to rhombs and fine granular aggregates and the frequent veining with well-crystallized pink and rose-red rhodochrosite is the simplest type of change that takes place. The changes that take place when the manganeseiferous opal crystallizes are more complex and result in a number of different minerals that have not yet been fully studied. The usual change is into a complex series of hydrous manganese silicates of various shades of yellow, orange, brown, and red brown. These vary widely in index refraction, double refraction, and optical properties. Usually they occur in minute fibers that are difficult to study. They first appear as irregular birefringent areas within the original manganeseiferous opal and as numerous irregular branching veins. The material developed within the opal is usually made up of minute, variously oriented, interwoven fibers. In the veins the fibers are usually elongated transverse to the vein. Sometimes several stages in growth of the vein may be shown by fibers of varying properties, such as index, birefringence, and optical elongation. Some of these fibers may be of the bementite type of hydrous silicate but there are many whose optical properties differ entirely from those of bementite. Microchemical tests indicate that they are essentially made up of manganous oxide, silica, and water. Iron oxide may be present in some. They are regarded as hydrous silicates of manganese, probably with or without a small amount of iron oxide. These will be more fully described in a future paper.

Rhodonite,  $\text{MnSiO}_3$ , so abundant in the Sierra Nevada, has been recognized in but one deposit, the Ladd mine, and in only one thin section where it occurs in a small vein associated with quartz. There it seems to be due to slight contact or hydrothermal action rather than simple recrystallization.

Inesite, a complex hydrous silicate of manganese and calcium having the general formula  $5\text{SiO}_2 \cdot 1\text{CaO} \cdot 4\text{MnO} \cdot 3\text{H}_2\text{O}$  and  $5\text{SiO}_2 \cdot 1\text{CaO} \cdot 3\text{MnO} \cdot 4\text{H}_2\text{O}$ , is of common occurrence in veins cutting the deposits that have been rather strongly recrystallized or subjected to weak hydrothermal action. It is readily recognized under the microscope and is not one of the hydrous manganese silicates previously mentioned. It always occurs as veins, generally of small size. Inesite has been fully described by Glass and Schaller.<sup>17</sup>

Original ores of the mixed type recrystallize to aggregates of granular manganese carbonate and the various hydrous manganese silicates previously mentioned. In such ores veins of rhodochrosite cut both carbonate and the recrystallized opal indiscriminately, as do the yellow to orange hydrous silicate veins. A highly complex vein pattern some-

<sup>17</sup> Glass, Jewell J., and Schaller, Waldemar T., Inesite: *Am. Mineralogist*, vol. 24, pp. 26-39, 1939.

times develops in such ores giving an illusion of the replacement of one substance by the other. Veins of quartz and chalcedony are common in all types of ores, except the pure carbonates.

Practically all stages of recrystallization may be observed under the microscope, from ores still containing much original amorphous manganese opal and spherulitic carbonate to those in which the opal has been completely converted into fibrous aggregates and veins and the carbonate into granular aggregates. On sharp folds, or wherever brecciation has been severe and veining intense, very confused aggregates are produced.

In places the manganese deposits have been intruded by basic and ultrabasic rocks and metamorphosed to varying degrees. Commonly the intrusions only cause baking and recrystallization similar to that just described, but in a few instances pneumatolytic contact metamorphism has taken place so that glaucophane-quartz rocks have developed from the cherts, and glaucophane schists from the shales. The writers never have observed the effects of pneumatolytic metamorphism on high-grade deposits but they have found manganese cherts that have developed, in addition to glaucophane, fibrous amphiboles that yielded thin coatings of black manganese oxide on oxidation.

There are several examples of low-grade deposits completely engulfed, with their inclosing cherts, in serpentine. A deposit of this kind occurs on the Hearst Ranch, 4 miles northeast of San Simeon, San Luis Obispo County, and there are several in the same belt of chert, inclosed in serpentine, on Manganese Peak in southern Tehama County. These deposits are all low grade and have never been mined and little is known regarding the changes that have taken place.

Hydrothermal alteration may produce striking mineralogical changes but it does not appreciably alter the form of the orebodies. Undoubtedly the hydrothermal changes are many and complex but little can be said about them as many of the details are obscure. However, there are some deposits that clearly owe their present mineral assemblage to hydrothermal action.

An example of an altered ore, probably altered by strong hydrothermal or contact action, was found near San Jose, but as it was not in place little can be said as to its origin. It occurred as a boulder on the bank of a creek near Alum Rock Park, San Jose, and had long been regarded, locally, as a meteorite, and in fact bore a placard stating it to be such. It was determined to be high-grade manganese ore in 1918 and broken and shipped, yielding several cars of ore. This occurrence, and its mineral content, has been described by Rogers,<sup>18</sup> who found it was largely composed of hausmannite,  $\text{Mn}_2\text{O}_3$ . Other minerals occurring with the hausmannite are: tephroite,  $2\text{MnO} \cdot \text{SiO}_2$ ; pyrochroite,  $\text{MnO} \cdot \text{H}_2\text{O}$ ; ganophyllite,  $7\text{MnO} \cdot \text{Al}_2\text{O}_3 \cdot 8\text{SiO}_2 \cdot 6\text{H}_2\text{O}$ ; rhodochrosite,  $\text{MnCO}_3$ ; barite,  $\text{BaSO}_4$ , and psilomelane (or a "psilomelane type" of black oxide formed by surface oxidation).

The rocks exposed in the steep hills immediately east of the location of the boulder are made up of Franciscan rocks in which there are many cherts and a few low-grade manganese deposits. The boulder probably came from some now completely eroded deposit.

The unusual assemblage of minerals indicates that it is the result of rather high-temperature hydrothermal action, possibly complicated

<sup>18</sup> Rogers, Austin F., An interesting occurrence of manganese minerals near San Jose, California: *Am. Jour. Sci.*, 4th ser., vol. 48, pp. 443-449, 1919.

by contact metamorphism. Hausmannite and barite have been found in several deposits in the Coast Ranges but the other rare manganese minerals in the San Jose boulder have not been reported.

Hausmannite is the chief ore mineral in several localities, notably in San Luis Obispo County and at the Blue Jay mine and neighboring prospects in Trinity County. Both hausmannite and braunite are found in very small quantities in a few other deposits but they are not common, except in the localities mentioned.

Even where hausmannite is most abundant it does not make up the entire deposit, usually being associated with rather well-crystallized rhodochrosite and the bementite-like silicates. At the Blue Jay mine, in Trinity County, hausmannite makes up over 75 percent of some of the ore, the remainder being rhodochrosite and various highly colored manganese silicates. The hausmannite occurs as grains, or aggregates of grains inclosed in, and also inclosing, the carbonates and silicates. Flakes of native copper and small stains of azurite are present; barite also is present. The cherts with which the ore is interbedded are intensely brecciated and veined. The condition of the cherts and the presence of native copper, azurite, malachite, and barite indicate that the deposit has been strongly altered since its deposition, probably by hydrothermal action.

Barite and native copper have been found in several other deposits, particularly that formerly operated by the Noble Electric Company in San Luis Obispo County, where hausmannite is abundant. Since barite occurs in several localities and is not uncommon in manganese deposits of other types than those described here it was thought desirable to see if it was present in the original little-altered ores. For this reason a specific request for BaO was made in the case of the analyses, previously presented, of the material from Humboldt and Mendocino Counties, made in the Herdsman laboratories, Glasgow. No trace of BaO was found in these or in the analyses made by the writers. Although this is not conclusive it suggests that it is not an essential constituent of the original syngenetic ores since it has not been found in any of the analyses of the unaltered materials.

It is believed that the barium and copper (probably originally a copper sulphide) were introduced at a later date and that the hausmannite was formed at the time of their introduction.

It is probable that a part of the mineral called hausmannite, occurring in a few of the Coast Range deposits, is braunite,  $3\text{Mn}_2\text{O}_3 \cdot \text{MnSiO}_3$ . This is suggested by the fact that when the material is dissolved in hydrochloric acid, gelatinous silica is formed. This is regarded as rather definite evidence of the presence of braunite.

Hausmannite, when pure, contains 72.05 percent metallic manganese. The so-called hausmannite ores of the Coast Ranges do not exceed 56 percent manganese and the average is slightly less. The ores, as mined, are mixtures of hausmannite, braunite, rhodochrosite, and hydrous manganese silicates.

It is possible that some of the hausmannite-braunite ores are original and represent local areas in which manganese was added in great abundance. However, all of the ores of this type studied by the writers have been formed from the original ores by hydrothermal action and contain small amounts of barium and copper, elements not found in the original syngenetic ores.

### Oxidation of the Manganese Ores

The end products of oxidation are black oxides of the pyrolusite and so-called "psilomelane" type, together with residual silica from the original ore, and small amounts of hydrous iron oxides.

The principal factors that control depth of oxidation are density of the original ore, amount of jointing and other fracturing, and the relative power of oxidation versus erosion in the particular locality. Orebodies that lie under gentle land slopes, where the rate of denudation of the surface is slow, are generally more deeply oxidized than those that outcrop on steep slopes. The deposits found in regions of heavy rainfall, such as the higher mountains of Mendocino County are, in general, less deeply oxidized than the orebodies in areas of moderate annual precipitation, such as the Coast Ranges of Alameda and San Joaquin Counties.

In the outcrops of some deposits of very dense, highly siliceous ore, the original minerals are found in the outcrop, coated by only thin films of black oxide. Here the denseness of the ore, and the protection of the manganese minerals by surrounding excess silica, have almost completely prevented oxidation. But with the less dense types of ores the only cases, known to the writers, where the original minerals occur in natural exposures, are in rugged regions of heavy rainfall in the northern Coast Ranges.

Where joint fractures and other types of openings are present, oxidation works its way along them into the orebody, as witnessed by the frequent occurrence of blocks of ore that are composed of a core of carbonate or manganiferous opal or both, surrounded by rims of black oxide. In the denser ores the oxidation may take place with little or no movement of manganese, but generally there is a migration of manganese from the interior of fracture-bounded blocks towards their peripheries. Proof of this is the frequent finding of blocks, within which there are residual cores of silica, devoid of manganese, whereas coatings or fissure fillings of high-grade (low-silica) black oxide occur on the exterior.

The residual masses of silica are composed of opal or chalcedony, or both, and represent the silica of the original ore, unchanged either as to site, physical form, or mineral composition. They are sometimes made up of plates, interlaced in such a way as to leave rhombic cavities; sometimes they are masses of finely porous silica, with no regularity in shape of pores. The first type is without doubt the result of removal of manganese carbonate from a carbonate-silica mixture. The latter are probably the residues from brown manganiferous opal. Both types of these siliceous skeletons are generally white in color, but not infrequently yellow; iron oxide occurs as a powdery coating.

The migration of manganese that attends the formation of the porous cores of silica amounts, at most, to a few inches. There is no evidence of any greater movement of the manganese. As an extreme case may be cited certain dense siliceous black oxide ores in which there are no residual cores of porous silica, and no other evidence of migration. These oxidized ores contain manganese and silica in the same proportion and mixed in the same way as in the original ore, and generally exhibit the same peculiar fracture and luster (for example, opaline, or resinous) as does the parent ore.

Although the enrichment of the ores by migration of manganese during oxidation is of little moment, there is evidence that suggests that enrichment of some deposits has occurred through removal of silica. There are several localities where the oxidized ore low in silica was mined, where, as soon as the original ore was reached, mining was stopped because the ore was too siliceous to market. As corroborative evidence might be cited the fact that quite a few occurrences are known of blocks of oxide ore, inclosed in soil, in which the ore is remarkably low in silica. But it is possible that such blocks came from primary ores that were originally quite low in silica.

As a rule there do not appear to be any intermediate stages of oxidation between the manganese oxide of the original manganese opal and carbonate and the black dioxides produced by oxidation. Under the microscope the change, which takes place along the edges and penetrates the interior along cracks, usually is sharp. However, in two cases, where the zone between the original material and the black oxides was examined under high power, minute red-brown needles appeared between the two. These have all the properties of manganite,  $Mn_2O_3 \cdot H_2O$ , and may be an intermediate stage in the oxidation of the  $MnO$ .

There is no evidence indicative of direct control of depth of oxidation by the water table, either present or past. Presumably oxidation of the ores could not have taken place below the lowest level that has marked the water table in any particular deposit. Only in rare cases has oxidation extended downward to the present water table. This is probably due to the diastrophic and physiographic history of the Coast Ranges. Strong folding and uplift occurred in the late Pliocene and again in the mid-Pleistocene, and erosion has been rapid and constant.

#### Previous Theories as to Origin

There have been few comprehensive studies of the manganese deposits of the Coast Ranges and, as a consequence, few theories advanced regarding their origin. As nearly as can be determined the early workers, except Penrose, regarded the deposits as replacements.

Penrose<sup>19</sup> noted the frequent occurrence of the ores in red "jaspers" which he thought, as did G. F. Becker, to be altered shales. The only statement made by Penrose regarding the origin of the deposits is as follows (p. 584):

"In the Coast Ranges of California, where the accompanying rock has been much altered by the conversion of shales into phthanite, or jasper, the manganese ore still remains in the state of oxide, without having formed to any extent other chemical combinations. The ores often contain considerable quantities of silica, and appear to be bedded deposits laid down at the same time as the enclosing rocks."

Evidently none of the deposits had been worked below the oxidized zone when visited by Penrose.

Harder,<sup>20</sup> in discussing the occurrence of the ores in the Coast Ranges states they are of two types, fault deposits and interbedded lenses. In a discussion of the origin of the various deposits studied, he states (p. 163): "The manganese ore occurs along heavy jasper beds as large masses replacing it, as veins, or merely as stains and partial replacements along cracks." Again on page 164, regarding the deposits in San

<sup>19</sup> Penrose, R. A. F., Jr., Manganese, its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. 1890, vol. 1, pp. 478-495, 584, 1891.

<sup>20</sup> Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, pp. 158-167, 1910.



Luis Obispo County, he states: "The manganese ore occurs in pockets and as irregular replacements along jasper lenses."

Mr. George Clarke Gester appears to have been the first to suggest that the black oxide ores were derived from manganese carbonate. This suggestion was made during an informal talk before the Le Conte Geological Club in 1917 and was based on the discovery of brown carbonate ore, below the black oxide, in the Ladd mine. The origin of the carbonate was not discussed.

Regarding the origin of the Franciscan deposits Harder and Hewett<sup>21</sup> state:

"Manganese in Jurassic Rocks. Jurassic rocks contain important deposits in central California. These ores are found in beds and lenses of jasper occurring at various horizons in the Franciscan shale and sandstone formation, of probable Jurassic age. The manganese ores, which are oxides near the surface, replace the chert and fill fractures in it. Most of the orebodies form pockets or irregular beds; but in a few places they occupy fault planes and fissures bounded by chert walls. Some of the surface ore is hard and massive, but some is porous and crumbly, as replacement of the chert is rarely complete, much of the ore is very siliceous. As explorations in many localities have not extended below the zone of oxidation, the source of the manganese is obscure but the fact that recently large quantities of rhodochrosite have been found in some of the California deposits indicates that, locally at least, the present ores are derived from the oxidation of manganese carbonate."

Thus the general opinion regarding the origin of the Coast Ranges deposits has been that they are replacements.

The theory held by the writers for the past 25 years has been briefly summarized by the senior author<sup>22</sup> in a general discussion of the Franciscan.

#### Conclusions as to Origin

The writers believe that they have presented sufficient evidence to prove that the manganese deposits of the Coast Ranges are syngenetic chemical sediments formed at the same time and in the same marine environment as the cherts with which they are associated. This conclusion is, of course, based on their firm conviction that the cherts are syngenetic chemical sediments deposited contemporaneously with the ordinary clastic sediments of the Franciscan-Knoxville group and in essentially the same form in which they now are found, except for the natural changes that take place with the passage of time and those due to diastrophism. The origin of the chert has been omitted purposely since it has been discussed so frequently. The evidence for the origin of the cherts has been presented in detail in the publications cited, particularly those by Lawson, Davis, and Taliaferro.

Not only are the ore lenses parallel to the bedding of the cherts but also they have the same form as the ordinary chert lenses. All details of outward form of ore and chert lenses are identical and this identity extends even to the inner textural features of both.

In addition to the evidence already presented it can be stated positively that even minor details of internal structure, such as evidence of gel contraction during formation, are formed in the original opaline ores just as in the opaline cherts. Contraction, during syneresis, toward definite and dispersed centers has been observed in the opaline manganese ores as well as in the cherts. Since these phenomena and their significance already have been discussed<sup>23</sup> the subject need not be reviewed

<sup>21</sup> Harder, E. C., and Hewett, D. F., Recent studies of domestic manganese deposits: *Am. Inst. Min. Met. Eng. Trans.*, vol. 63, p. 19, 1920.

<sup>22</sup> Taliaferro, N. L., Franciscan-Knoxville problem: *Am. Assoc. Petroleum Geologists Bull.*, vol. 27, pp. 147-153, 1943.

<sup>23</sup> Taliaferro, N. L., Contraction phenomena in cherts: *Geol. Soc. America Bull.*, vol. 45, pp. 189-232, 1934.



here, except to state that they prove that the opaline ores passed through the same stages of gel contraction as the silica gels forming the cherts.

No evidence of replacement of chert by original ore has been observed in the scores of deposits examined by the writers or in the hundreds of thin sections examined under the microscope. On purely theoretical grounds it might be assumed that replacement occurred at the time of formation, when the manganese, either in colloidal form or in solution, diffused into the silica gel or into the original siliceous oozes from which the cherts were formed. It is quite possible that diagenetic changes and practically contemporaneous replacements occurred, but of this there is no direct evidence, except, possibly, the partial and complete replacement of Radiolaria. However, as has been stated, this is susceptible of other interpretations.

After a consideration of all of the available evidence the writers have no hesitancy in stating they believe that both the cherts and the original ores are syngenetic chemical sediments deposited at the same time and under the same conditions, and that the ordinary processes governing the formation of the cherts also controlled the formation of the original ores. They do not believe that the evidence they have observed permits any other interpretation. This conclusion is not based on a study of a few deposits but on the examination not only of most of the mines and prospects of the Coast Ranges, but also on hundreds of occurrences of manganese in cherts that are too low grade even to be called prospects.

Subsequent changes, resulting in recrystallization of the original ores and the formation of new minerals, frequently have been extensive, but they have not materially altered the form of the orebodies or their relation to the cherts.

#### Source of the Manganese

So close is the association of manganese, iron, and silica in the Coast Ranges that the writers believe that they must have had a common origin. This, of course, must be regarded as an empirical theory since it is not susceptible of proof but is based upon experience, that is, the almost universal association of the three, not only in the region under consideration but in many places throughout the world. To the writers it appears to be, at least, a reasonable assumption.

The observed facts that appear to have a bearing on the source of the silica, manganese, and iron may be briefly outlined as follows:

1. There is a close association, both in time and space, between the basic volcanics of the Franciscan-Knoxville group and the cherts. It is an undeniable fact that the formation of the cherts did not begin until the beginning of volcanism and that, with an exception previously mentioned, the greatest development of cherts always coincides with maximum volcanism. As the contemporaneous volcanics become fewer in number and disappear laterally the cherts likewise become less abundant and disappear.
2. Cherts of the Franciscan-Knoxville type are commonly associated with basic volcanics in many places throughout the world. The association of the two is so constant that it does not appear to be merely fortuitous.
3. Siliceous springs or siliceous deposits are exceedingly common in volcanic regions and both iron and manganese are sometimes associated with both the silica-bearing waters and the sinters they form. There is an extensive literature regarding this subject with which the writers are familiar but which will not be cited since it is so well known.

4. Basalts and similar basic rocks have a higher average manganese content than any other igneous rocks. Although there are no complete analyses of Franciscan-Knoxville basalts they are frequently stained and filmed with manganese and iron and, as shown by Davis, sometimes actually have manganese-iron deposits directly associated with them.

To the writers the first appears to be the most convincing argument. They further believe that if the volcanics are the source of the silica they are likewise the source of the manganese and iron.

Several possible methods of derivation of the silica from the basic volcanics have been suggested; these also would apply to the manganese and iron.

A number of geologists, including Lawson and Davis, have suggested that the silica forming the radiolarian cherts was largely derived from submarine siliceous springs arising from the volcanics. Dewey and Flett's <sup>24</sup> concept of the exhalation of vapors and solutions, rich in sodium silicate, from cooling spilitic lavas (albitized pillow basalts) is, in reality, merely a variant of the siliceous spring theory. They showed that the British pillow lavas, which are associated with red radiolarian cherts, had been altered at the time of or shortly after their extrusion, and suggested that sodium silicate was one of the products of alteration. The Franciscan pillow lavas also were greatly albitized and epidotized at the time of their intrusion and may have behaved in the manner suggested by Dewey and Flett.

Another slight variant would be the theory of interaction of the hot sea water with the hot lavas, yielding gelatinous silica, or the leaching of the lavas by waters passing through them. It is possible that the silica and the iron might have been derived by any one or all of these methods, both being universally present in the basalts. If the manganese was derived by leaching or interaction of the sea water with the hot lavas the cherts should be universally stained with manganese, as they are with iron, unless the manganese content of different flows varied remarkably.

In connection with the submarine spring theory the observations of Behrend <sup>25</sup> regarding the discharge of considerable quantities of iron from submarine volcanic springs near Santorin, in the Mediterranean southeast of Greece, should be mentioned. A strong discoloration of the sea in the vicinity of Santorin has been observed at various times since 1650. The discharge of iron carbonate is said to have been practically continuous from 1707 to 1848 and from 1869 to 1933. The sea in the vicinity was colored yellow, green, and red over a considerable area, especially during the volcanic eruptions when the submarine springs seem to have been most active. However, the springs discharge iron carbonate and gases even during periods of quiescence. The water from the springs is said to be a dirty dark-green color, changing to brownish yellow and red with the appearance of iron hydroxide. The green color is due to ferrous carbonate; iron chloride also is reported to be present. The iron hydroxide formed at the surface sinks and covers the sea bottom in the region. Such springs might well give rise to the type of deposit, found in Lake County, and described by Davis.

<sup>24</sup> Dewey, H., and Flett, J. S., On some British pillow lavas and the rock associated with them: *Geol. Mag.*, vol. 48, 1911.

<sup>25</sup> Behrend, Fritz, Eisen und Schwerfel Fordende Gasquellen auf den Kemeni Inseln, in Reck, Hans, Santorin. Die Werdegang eines Vulcans und sein Ausbruch, 1925-1928, vol. 2, pp. 323-328, Berlin, 1936.

Magmas unusually rich in manganese probably would behave in the same way, giving off manganese carbonate and oxide.

The association of the Coast Range manganese deposits with the thicker more massive chert lenses appears to be the only direct evidence of the manner in which the manganese was added to the sea water. As previously stated these massive cherts indicate either a more rapid addition of silica locally or its more rapid coagulation. Since there are many massive chert lenses that do not contain manganese it can not be argued that the presence of manganese caused more rapid coagulation. It is believed that these thicker massive lenses indicate a more rapid addition of silica locally. This appears to be the only evidence that would favor the submarine spring theory over the unlocalized discharge or sodium silicate, the interaction of sea water and hot lava, or the leaching of the lavas.

It is believed that the evidence presented favors the concept that the manganese was added rapidly and that its addition coincided with a more rapid, local addition of silica to the sea water. The form, or forms, in which the manganese was introduced is not known but it is believed to have been in the form of manganese carbonate and manganous oxide. The exact method of its precipitation is not known. There is no indication that reducing conditions were necessary as both the manganese carbonate and manganiferous opal ores are associated with cherts in which the iron is in both the ferrie and ferrous states.



# MANGANESE DEPOSITS OF THE SIERRA NEVADA, THEIR GENESIS AND METAMORPHISM

By N. L. TALIAFERRO\*

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## INTRODUCTION

Manganese deposits are widespread throughout the Sierra Nevada, being found in every county from Fresno northward to Plumas.

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Although the majority of the deposits are of relatively little economic importance at the present time, chiefly because of the siliceous nature of most of the original ores and the comparatively shallow depth to which most of them have been oxidized, they have many features of interest from the standpoint of their origin, mode of occurrence, and the various types and degrees of metamorphism to which they have been subjected.

During an investigation of the manganese and chrome deposits of the Sierra Nevada in 1917-18 the writer visited all the known mines and prospects at least once, and a few several times, over an area more than 270 miles in length and 30 miles in width. A number have been visited since that time. More than 500 thin sections of the ores and the associated rocks have been examined but no quantitative chemical work has been done.

The early work done in connection with the manganese investigation was directly responsible for the writer's subsequent attempt to revise the geology of a part of the Sierra Nevada. At the time the early work was carried out it was impossible to assign, with any certainty, many of the deposits to any described or named group of rocks, or to make any reasonable age assignment. For the past 18 years the writer has spent a part of his available time in a revision of the stratigraphy and structure of that part of the Sierra Nevada west of the Mother Lode and feels that he now can place all of the Jurassic and some of the Paleozoic deposits in their correct stratigraphic position. The results of the stratigraphic and structural work will be presented in a future paper and hence will be only briefly mentioned here.

The manganese deposits occur both in the Jurassic and in the Paleozoic (one of no economic importance occurs in the Tertiary) and exhibit widely different degrees of metamorphism. Some have only experienced moderate dynamic action, the associated sediments having reached the slate stage, while others occur in roof pendants in granodiorites and have been intensely metamorphosed.

Their mode of occurrence is very similar to the manganese deposits of the Coast Ranges in that they are directly associated with radiolarian cherts and volcanics or their metamorphosed equivalents.

The writer has examined more than half of the known manganese deposits of the Coast Ranges, where neither the deposits nor the associated rocks have been metamorphosed to the same extent as those in the Sierra Nevada. The experience gained in a study of the comparatively little-altered Coast Range deposits was of great assistance in the interpretation of some of the more highly metamorphosed deposits of the Sierra Nevada. The mode of occurrence and genesis of the Coast Range deposits are described by Dr. F. S. Hudson and the writer in another paper in this bulletin.

#### ACKNOWLEDGMENTS

The writer is greatly indebted to Mr. Theo H. Crook, who not only assisted him in the field for five months in 1918 but who, during the present year, 1943, has given freely of his entire time in the preparation of a bibliography. Thanks also are due G. D. Louderback, E. F. Davis, and F. S. Hudson, all of whom spent a few days in the Sierra Nevada with the writer and with whom he has discussed many phases of the problem.

## PREVIOUS LITERATURE

Brief statements relative to the occurrence of manganese in the Sierra Nevada of California have appeared from time to time, but as yet no connected account of its mode of occurrence and origin has been presented.

Prior to the demand for domestic manganese ore created by war conditions in 1917, no ore had been shipped from this region. In fact, no systematic search for such ore had been made before 1915. A few deposits had been prospected, not for their manganese content, but as possible sources of gold. Quartz veins occur in many of the deposits and this was undoubtedly the cause of prospecting during the early gold excitement. Usually this work consisted of trenching to a depth of a few feet but, in the vicinity of Sonora, in Tuolumne County, a shaft is said to have been sunk to a depth of about 30 feet before the prospector was convinced of the absence of gold.

The earliest account of manganese in the Sierra Nevada is by Penrose,<sup>1</sup> who briefly described all of the known deposits, but who did not discuss their origin. Brief mention is made of a few occurrences in the Bidwell Bar,<sup>2</sup> Jackson,<sup>3</sup> and Mother Lode district folios.<sup>4</sup>

Harder<sup>5</sup> gives a resume of all the known deposits, some five in number, but the only statement made regarding the origin is as follows:

"Two miles northeast of San Andreas, Calaveras County, it [manganese] is found as oxide in mica schists of the same formation [Calaveras]. The principal occurrences are on Fortner's ranch, where the ore is found in small quartz lenses a few feet in width, running parallel to the schistosity of the inclosing mica schists. These quartz masses may be recrystallized jasper lenses or they may be later veins related to the gold-bearing quartz veins along the mother lode."

The California State Mining Bureau issued a bulletin on manganese and chromium in California in 1918<sup>6</sup> but no connected account of the occurrence of the ores or of their character is given and the origin of the Sierra Nevada deposits is not considered. The only statements made are as follows:

"The black oxides of manganese occur commonly in irregular shaped bodies inclosed in lenses of quartz, and as far as visited by the field men of this Bureau, appear to differ entirely from the Coast Range deposits."

In describing the Crocker-Preston deposit in Amador County it is stated that<sup>7</sup>

"there is a mineralized zone which strikes W. of N. traceable from Volcano for 2 miles southward, and was then observed by the writer at two points at least one-half mile apart. This zone appears to be at least 100 feet wide, and is on a contact between limestone on the hanging wall (east) and a schist on the west. The dip is steep. The bulk of this material is siliceous, being a quartzite of the Calaveras series. There is also some quartz mica schist. Within this zone and striking more or less parallel with it are lenses of manganese ore, some of which resemble mineral springs' deposits filling fissures in disturbed areas of the enclosing formation."

These constitute practically all of the publications dealing with manganese in the Sierra Nevada.

<sup>1</sup> Penrose, R. A. F., Jr., Manganese: its uses, ores, and deposits: Arkansas Geol. Survey Ann. Rept. 1890, vol. 1, pp. 491-495, 1891.

<sup>2</sup> Turner, H. W., U. S. Geol. Survey Geol. Atlas, Bidwell Bar folio (no. 43), 6 pp., 3 maps, 1898.

<sup>3</sup> Turner, H. W., U. S. Geol. Survey Geol. Atlas, Jackson folio (no. 11), 6 pp., 4 maps, 1894.

<sup>4</sup> Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Mother Lode district folio (no. 63), 11 pp., 8 maps, 1899.

<sup>5</sup> Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, pp. 164-165, 1910.

<sup>6</sup> Bradley, Walter W., et al., Manganese and chromium in California: California Min. Bur. Bull. 76, 1918.

<sup>7</sup> Bradley, Walter W., et al., *op. cit.*

### SKETCH OF THE GEOLOGY OF THE SIERRA NEVADA

Only a brief sketch of the general geology of the Sierra Nevada will be given and this only as a background for the discussion of the manganese deposits.

The two chief sedimentary groups of rocks recognized in the early folios and publications on the Sierra Nevada are the Calaveras and the Mariposa. The writer <sup>8</sup> has proposed a new group, the Amador, that is divisible into several formations. Thus far only brief mention has been made of the general nature and structure of the Amador; a more complete description will be given in a future paper.

#### The Calaveras

This is the name given to the pre-Mesozoic bedrock of the Sierra Nevada, south of the Taylorsville region. Only in the Colfax <sup>9</sup> region has the Calaveras been divided into formations. The name is a catchall for all the Paleozoic rocks of the Sierra Nevada and hence has no stratigraphic significance. In the Taylorsville region Diller <sup>10</sup> described Paleozoic formations ranging in age from the Silurian to the Carboniferous; later work has shown that the Permian is represented also. In conformity with the usual practice of the time, Diller grouped all of the supposed Carboniferous formations under the name Calaveras. South of the Taylorsville region all the Paleozoic rocks, even where subdivided into formations, have been placed in the Calaveras group and assigned to the Carboniferous, generally on far from satisfactory evidence. Practically all of the fossils found have come from lenses of limestone; because of the recrystallization of the limestones the preservation is poor. Notwithstanding the fact that the fossils, in the great majority of cases, indicate nothing more than a Paleozoic age the Calaveras invariably is stated to be Carboniferous on the legends of the various geologic maps of the Sierra Nevada. Undoubtedly the Carboniferous is represented, but the writer is of the opinion that at least a part of the Calaveras is Permian and a part pre-Carboniferous. Manganese deposits occur at more than one horizon in the Calaveras and while it is certain that some of them are Carboniferous, possibly Mississippian, it is probable that some of them are older. This is indicated by the fact that beds of the same type exhibit considerable variation in degree of metamorphism, a variation that does not always appear to be dependent on proximity to intrusive batholiths.

As would be expected a great many rock types are represented in the heterogeneous assemblage known as the Calaveras group, and these show a wide range in type and in degree of metamorphism. Both sedimentary and volcanic rocks are present and these are cut by a great variety of intrusives. The writer has not made a systematic study of the structure, stratigraphy, or lithology of these rocks except in small, local areas, and only brief mention will be made of the rock types, other than those directly associated with the manganese deposits, which will be more fully described in a later section.

<sup>8</sup> Taliaferro, N. L., Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. American Bull., vol. 53, pp. 71-112, 1942.

<sup>9</sup> Lindgren, W., U. S. Geol. Survey Geol. Atlas, Colfax folio (no. 66), 10 pp., 4 maps, 1900.

<sup>10</sup> Diller, J. S., Geology of the Taylorsville region: U. S. Geol. Survey Bull. 353, 128 pp., 5 pls., 1908.



The Calaveras as a whole has suffered considerable metamorphism, both dynamic and contact. In some areas the changes are clearly due to dynamic action alone, in others, to a combination of dynamic and thermal action. The most extreme changes occur on the contacts of large intrusives and in roof pendants in batholiths. The rocks also have frequently been hydrothermally altered and sometimes crushed and mylonitized along fault zones. In places several of these types of metamorphism have been combined, resulting in almost complete alteration.

One of the commonest rock types of the Calaveras, and one which is widely distributed as long bands of varying width was originally a dark clay-shale. In its least altered form this rock has reached an advanced slate stage; usually the Calaveras rocks that have been described as slates have really passed that stage and are phyllites. Newly formed mica is nearly always present and the rocks have a bright sheen on cleavage surfaces. Interbedded with these are white, blue-gray, and black recrystallized limestones and sheared sandstones. Both the altered sandstones and the limestones may occur in rather wide bands with few phyllite intercalations. With increased metamorphism these pass into fine to coarse quartz-mica schists and marbles. The sandstones appear to have been feldspathic and they may pass into gneisses. Graphitic schists result from originally highly organic shales or shaly limestones. Conglomerates are of frequent occurrence and in these the pebbles are generally crushed and elongated. With extreme metamorphism they may pass into augen gneisses and flasers. Cherts are commonly present and range from rhythmically bedded, slightly recrystallized red radiolarian cherts to completely recrystallized white to gray quartzites. These will be described more fully under the discussion of the Calaveras manganese deposits.

Interbedded with these sediments and also forming long belts sometimes more than a mile in width are volcanics in various stages of metamorphism. Some of the flows are so little altered that tops and bottoms may be distinguished by the distribution of vesicles; others have been completely converted into schists. Acid flows and tuffs sometimes are present, but the majority appear to have been andesitic and basaltic. Pillow basalts are not uncommon, especially in association with the comparatively little-altered red radiolarian cherts. They may be common, but metamorphism and crushing usually obliterate the pillow structure. The great majority of the volcanics are decidedly schistose, having been converted into chlorite schists, chlorite amphibolite schists, amphibolite schists, and massive amphibolites; the latter usually result from thick flows or shallow intrusives. In some cases the original rocks were clearly augite andesites, but in many cases their exact original composition is unknown because of the changes that have taken place. The great bulk of the green schists appear to have been intermediate and basic volcanics originally.

Intrusive into both the metamorphosed sediments and volcanics are a wide range of hypabyssal and plutonic rocks. Among the plutonic rocks are granites, granodiorites, quartz diorites, diorites, and gabbros. Basic and ultrabasic rocks, now largely serpentized, are common but these are not necessarily plutonic. Many of them appear to have been emplaced prior to the folding at a relatively shallow depth. The great bulk of these appear to have been intruded in the late Jurassic since they cut the Amador and Mariposa, as well as the Calaveras. The grano-

diorites were intruded after the folding of the region which took place in the late Kimmeridgian. It has been stated that there are pre-Mesozoic plutonic intrusives cutting the Calaveras that are strongly gneissic, having been emplaced prior to the Nevadan revolution. Batholithic intrusion may have taken place in the late Paleozoic, but the evidence is not particularly convincing. The great bulk of the plutonic intrusives were emplaced in the Mesozoic. The serpentines are clearly earlier than the granodiorites.

In addition to the large masses of acidic, basic, and ultra-basic rocks there are innumerable dikes, plugs, and small irregular intrusions. Some of these are contemporaneous with the Calaveras and represent the feeders and intrusives associated with the flows and tuffs; others are clearly differentiates of the later large intrusive bodies, and it is in this class that the largest number of extreme types are found.

The Calaveras group, as previously defined, extends throughout the Sierra Nevada. Little is definitely known regarding its extent south of Tulare County, but certain schists and marbles that occur as roof pendants in the granodiorites as far south as Kern County probably belong to this group. It would not be stretching the very elastic limits of the name Calaveras to include them in the group.

In the central part of the Sierra Nevada most of the Calaveras lies to the east of the Mother Lode, which represents a great late Jurassic thrust fault which brought the Calaveras westward over the Jurassic rocks. No Mesozoic rocks occur to the east of the Mother Lode until the crestal region is reached, where late Triassic and Jurassic rocks lie in a great syncline, often partially or even completely obliterated by batholithic intrusions. These relations have been briefly described by the writer.<sup>11</sup>

West of the Mother Lode, the Calaveras is brought up in the midst of the Jurassic along a large, compound, often highly faulted anticline. In places, as along the Cosumnes River, there is but a single belt of Calaveras flanked by Amador, but in other places, as on the Calaveras River, there are several narrow belts of Calaveras repeated by faulting. In the various Sierran folios, the belt east of the Mother Lode is called the Eastern Belt of the Calaveras, and the narrower one to the west is spoken of as the Western Belt.

The large, complex anticline that exposes the Calaveras west of the Mother Lode plunges southward from the Calaveras River. On the Stanislaus River there is only a very narrow faulted belt of Calaveras in the midst of the Amador and Mariposa. South of the Stanislaus River the western belt of Calaveras plunges beneath the Jurassic rocks and is not again exposed.

The Calaveras has been very strongly folded and stands at high angles. The schistosity is sometimes parallel to the original bedding, but frequently the two are at a marked angle, especially in the crests and troughs of folds and on the plunges.

#### The Amador Group

As the result of a number of years of work in the Sierra Nevada, the writer has separated a new group of rocks that is clearly younger than the Calaveras and older than the Mariposa. The separation of this

<sup>11</sup> Taliaferro, N. L., Geologic history and correlation of the Jurassic of southwestern Oregon and California. Geol. Soc. America Bull., vol. 53, pp. 71-112, 1942.

group has proven very helpful in the determination of the structure of the older rocks west of the Mother Lode. The only detailed work on this group has been between Placerville and the southern end of the Indian Guleh quadrangle, a distance of 110 miles, but it is known to extend from the Middle Fork of the American River to Fresno County, a distance of 180 miles. North of the Middle Fork of the American River it appears to have been overlapped by the Mariposa; the exact manner and point of overlap are not known as the relations have been obliterated by a plutonic intrusion.

On the various published geologic folios of the Sierra Nevada this group of rocks has been mapped as Calaveras, Mariposa, "diabase and porphyrite," amphibolite schist, and quartz amphibolite. As a specific instance of its confusion with the Calaveras may be cited the section on the Cosumnes River (Placerville folio) below Huse bridge on the Mother Lode Highway. Here the lower part of the Amador on both sides of the anticlinal belt of western Calaveras has been mapped with the Calaveras notwithstanding the fact that it rests unconformably on the Paleozoic with a thick basal conglomerate on both sides of the overturned antiline. The upper part of this section has been mapped in that very convenient catchall, "diabase and porphyrite."

The type section for the northern end is on the Cosumnes River, and the type section for the southern end is on the Merced River. On the Cosumnes River immediately west of the Mother Lode Highway it is 7100 feet thick; it is much thicker to the west on the same river, but no exact measure can be obtained because of the acute folding. On the Merced River, it is fully 14,000 feet thick, but the base is not exposed.

On the Cosumnes and Calaveras Rivers, it is readily divisible into two formations, the Cosumnes below and the Logtown Ridge agglomerates at the top. On the Merced River it is divisible into five formations which are, from base to top, the lower volcanics (thickness unknown as the base is not exposed), the pillow basalts (1200 feet thick), the Hunter Valley cherts (950 feet thick), the Peñon Blanco volcanics ( $9000 \pm$  feet thick), and the Agua Fria (3500 feet thick). Because of the great lateral variation in these rocks it is impossible, as yet, to establish a complete correlation between the two sections. However, the Logtown Ridge and the Peñon Blanco may be definitely correlated, and the pillow basalts and Hunter Valley cherts are equivalent to a part of the Cosumnes formation.

The Cosumnes formation, on the river of the same name, rests unconformably on the Calaveras (Clipper Gap formation) with a thick basal conglomerate containing abundant debris of the underlying Paleozoic. The basal beds consist of alternate sandstones and conglomerates 1200 feet in thickness. These pass upward into sheared arkosic sandstones and dark clay-slate which, in turn, grade upward into thin-bedded tuffs and fine sediments. Basic flows and red and green cherts are sometimes present in the upper part. The Cosumnes formation is 4400 feet thick to the east of the Calaveras anticline, but is much thicker on the west because of the presence of numerous rhyolite flows and agglomerates. The Logtown Ridge volcanics consist of flows, tuffs, and fine to coarse augite andesite agglomerates; they are 2700 feet thick along the west side of the Mother Lode Highway but thin and become finer in grain toward the west where they are several times repeated by folding. Manganese

deposits occur in cherts in both the upper part of the Cosumnes and in the Logtown Ridge agglomerates. The Hunter Valley cherts and pillow basalts will be described in connection with the Amador manganese deposits.

The Amador is in the same stage of dynamic metamorphism as the Mariposa; the original clay-shales are now slates and the augite andesite tuffs are largely converted to amphibolite and chlorite schists<sup>12</sup>; they are in the high epizone stage. On plutonic igneous contacts the Amador is greatly metamorphosed, the slates either being thoroughly hornfelsed or converted into andalusite schists and the basic volcanics into coarse hornblende schists. On serpentine contacts they sometimes show pneumatolytic contact effects, being changed into actinolite-garnet-sphene schists or, more rarely, into glaucophane schists. Hydrothermal alteration frequently takes place, resulting in sericitization and silicification in local shear zones.

Batholithic intrusions of granodiorite and diorite are common in the Amador, as are plugs, sills, and dikes of basic and ultrabasic rocks; the ultrabasic rocks practically always are completely serpentized. Dikes, sills, plugs, and irregular intrusions of quartz porphyry, feldspar porphyry, and augite andesite are very common.

Nearly everywhere the Amador grades upward into the Mariposa. However, in the northeastern part of the Indian Gulch quadrangle, the Mariposa rests with slight angular discordance on the lower beds and has a thin basal conglomerate made up of Amador (Agua Fria formation) debris. North of the Middle Fork of the American River, the Mariposa appears to overlap the Amador.

The Amador occurs as long, usually rather narrow belts, either flanking the western Calaveras or rising as overturned anticlines from beneath the Mariposa. There are no less than seven such repetitions of the Amador in overturned anticlines along the Stanislaus River between Melones Dam and Gopher Ridge. Practically always these are overturned toward the west, the axial planes of the folds dipping eastward at angles of 60 to 70 degrees.

The exact age of the Amador is not known, but it is believed to extend from the upper Middle to the lower Upper Jurassic. As has been previously shown by the writer, the best available evidence indicates that the Mariposa is Oxfordian and, possibly, lower Kimmeridgian. Ammonites have been found in several places in both the Cosumnes and Logtown Ridge formations, but they are usually distorted. These have not as yet been studied in detail but, according to Professor S. W. Muller, they are unquestionably Jurassic. The most significant fact regarding the age of the Amador is that no Aucellas, the most abundant fossils in the Mariposa, have been found in the Amador. The writer never has found Ammonites in the Mariposa without finding abundant Aucellas; but on both the Mokelumne and Cosumnes Rivers he has found abundant Ammonites in the Amador, but no Aucellas. This would indicate that the Amador is older than the Oxfordian.

<sup>12</sup> The writer is opposed to the terminology of Tyrrell (Text Book of Petrology) who describes slates as due to cataclastic metamorphism and schists as due to dynamic metamorphism. In both the Amador and Mariposa the clay-shales have been converted into slates and the interbedded andesitic volcanics into chlorite and amphibolite schists. Rhyolite tuffs are converted into thoroughly schistose quartz-mica schists. All are clearly in exactly the same stage of metamorphism as they occur in many thin repeated interbeds.

### The Mariposa

Since no manganese deposits are known to occur in the Mariposa, it will only be briefly mentioned. This formation consists predominantly of dark clay-slates with minor amounts of sheared sandstone and conglomerate. Volcanics are present in places, evidently the result of local submarine explosions. Andesite flows and tuffs are the usual types, but, in places, especially south of the Merced River, there are a few thin rhyolite flows and tuffs. No cherts have been observed in the Mariposa. It is intruded by the same general types of plutonic and hypabyssal igneous rocks as the Amador. On granodiorite contacts the slate is characteristically converted into andalusite or chiastolite slate, schist, and hornfels. It occurs in long parallel, essentially synclinal, belts that form areas of comparatively low relief. The Mariposa, because of its highly incompetent nature, is usually intricately folded; the soft shales yielded readily to compression. The nature of the folds can be determined only when there are interbeds of sandstone or conglomerate. Drag folding, pointing out the position of the major folds, is characteristic.

The Mariposa practically always forms a long, complex, often faulted, syncline immediately west of the Mother Lode thrust.

### Structure of the Bedrock Complex

The bedrock complex of the Sierra Nevada is made up of the Calaveras, Amador, and Mariposa together with the igneous rocks that intrude them.

The separation of the Amador has enabled the writer to work out the intricate structure of that part of the Sierra Nevada west of the Mother Lode, and has shown the existence of many folds and faults. The structure sections accompanying the Sierran folios show a continuous high easterly dip broken only by intrusions, a concept that is the result of the consideration only of the prevailing direction of cleavage and schistosity, and not of the original bedding. The bedding is best studied in the deep river canyons where the rocks are well exposed and unweathered, as weathering tends to bring out the cleavage and obscure the bedding. It is possible to stand in the bottom of a deep canyon and see very low dipping bedding planes on crests or troughs of broad folds, and then to look up on the canyon rims and see what appears to be bedding dipping at a very high angle to the east; the apparent bedding near the weathered surface is the cleavage that is imposed on all incompetent and moderately competent rocks. The competent Amador, especially the thin-bedded tuffs, cherts, and flows, is especially valuable in making visible the details of folding. The folds and faults are readily worked out both by bedding planes and the distribution of the various units. After the folds have been found in the rivers, they may be traced along the weathered upland surfaces by the distribution of the units. The competent Amador tends to form ridges, and the Mariposa slates, valleys. The repeated long belts of Mariposa, often bifurcated or containing apparent lenses of "diabase" or "porphyrite," shown on the folios of the Sierra Nevada, are the result of folding. An account of the structure, accompanied by sections, will be given in a future paper.

The batholithic masses were intruded after the folding of the beds. The folding took place in the late Kimmeridgian or early Portlandian, but the batholithic invasions are less susceptible to accurate dating; they

are believed to have been emplaced in the very late Jurassic or possibly in the early Lower Cretaceous. The writer has mapped a number of folds and lithologic units into one boundary of small batholiths and found the same folds and units exactly along their projection on the opposite boundary. Bending of either cleavage or bedding about batholithic bodies occurs, in a few rare cases only, on the eastern and western margins of bodies elongated parallel to the general structure; these may be rare examples of crowding aside of the invaded rocks.

The complex Cretaceous and Tertiary history of the Sierra Nevada will not be treated here since the only Tertiary manganese deposit is of no economic importance. It is sufficient to say that the events of these important chapters in geologic history did not modify the complex internal structures, but only the outward form of the range. Tertiary volcanics and sediments lie at low angles on, and lap onto, the western margin of the range, covering the bedrock complex in many places.

### THE MANGANESE DEPOSITS

#### General Statement

The manganese deposits of the bedrock complex of the Sierra Nevada are syngenetic and are always associated with cherts or meta-cherts. They partake of all the folding and faulting shown by the bedrock and show the same stage of metamorphism as the enclosing rocks.

Three terms descriptive of the materials of the deposits should be defined at the outset. By the term original or syngenetic materials is meant the substances as they were originally deposited. By primary ore is meant either the original substances or the minerals, such as rhodonite or spessartite, developed from them by contact or dynamic metamorphism. Oxide ore is the product of surface oxidation of either the original or primary substances. Oxidation usually has not extended to any depth. Practically all deposits on steep slopes show only surface films of black oxide.

#### The Calaveras Deposits and Associated Rocks

The manganese deposits in the Calaveras group are always associated either with unmistakable red radiolarian cherts or with what has generally been called "quartzite" but which is, in reality, meta-chert.

The unmistakable, rhythmically bedded red and green radiolarian cherts and shales either occur in the upper part of the Calaveras or are remote from batholiths. Since Radiolaria are clearly visible in thin section there can be no question as to their original nature. These are practically identical with the radiolarian cherts of the Franciscan-Knoxville group of the Coast Ranges in every particular, except age and the usual more advanced degree of recrystallization. They are usually made up of a cryptocrystalline aggregate of chalcedony or a fine quartz mosaic identical with the more recrystallized cherts of the Franciscan. Furthermore, they show the same details of bedding, including the presence of more massive lenses, in which the manganese deposits occur, enclosed in thin-bedded cherts and shales. Since the details of the bedding and the significance of the more massive lenses has been discussed<sup>13</sup> the subject need not be reviewed here.

<sup>13</sup> N. L. Taliaferro and F. S. Hudson, *Genesis of the Manganese Deposits of the Coast Ranges of California*, this bulletin.

In nearly every section of the Calaveras group are found one or more horizons of dense siliceous rock or fine-grained quartz schists. Such rocks are variously described in the folios covering this district as phthanites, "fine-grained siliceous rocks of a chert-like appearance," "quartz-schists," "siliceous argillites," and "cherts." With the exception of some of the more coarsely crystallized bodies, which have been considered to be very pure, fine-grained quartz sandstones, none have been regarded as original sediments. A few have been ascribed to the silicification of slates but the great majority have been described as metasomatic replacements of limestones by silica.

Lindgren<sup>14</sup>, however, has described massive "siliceous argillites" from the Federal Loan area near Nevada City which contain small round clear spots of quartz aggregates which he considered as possibly representing almost obliterated radiolarian remains.

Before discussing the origin of these highly siliceous rocks a description of their field occurrence and microscopic appearance will be given.

Rocks of this nature occur either as relatively small lenses in phyllites, or siliceous schists, as large lenses made up of regularly bedded layers separated by thin partings of quartz-sericite or quartz-mica schists, or as belts of considerable thickness and extent. All gradations exist between these three types. The small lenses never occur singly but in groups or trains of lenses along approximately the same horizon. These are usually rather massive and show only occasional bedding. The planes, which are always parallel to the schistosity of the enclosing slate or schist, are determined by thin partings of mica-schist. In size the individual lenses vary from a few feet up to one hundred or more feet in length.

The large lense-like areas and the more or less continuous belts are identical in appearance and it is quite possible that detailed mapping would show that the larger belts are made up of a number of lenses separated by slate or schist.

In some areas these highly siliceous rocks show remarkably even, rhythmic bedding, the almost pure siliceous bands being separated by thin partings of siliceous slate or quartz-mica schist. The quartzose layers vary from a quarter of an inch to a foot or more in thickness, while the schist partings rarely exceed half an inch and are usually much thinner. Within these rather thin-bedded rocks, beds or lenses of more massive quartz rock are of frequent occurrence. These vary from a few feet to 20 or 25 feet in thickness, and usually stand out boldly above the regularly bedded areas. Both the thin-bedded and massive types are frequently stained with iron or manganese and locally the latter occurs in minable masses. It is in such rocks that practically all of the Calaveras manganese deposits occur.

These rocks are often highly contorted and show numerous small intricate bendings and twistings. This is shown in an accompanying illustration.

The appearance of these rocks in the hand specimen depends largely on the degree of metamorphism. The less metamorphosed are exceedingly dense homogeneous rocks sometimes dull and flinty and sometimes with

<sup>14</sup> Lindgren, W., The gold-quartz veins of Nevada City and Grass Valley districts, Calif.: U. S. Geol. Survey, 17th Ann. Rept., pt. 2, pp. 80-81, 1896.



a marked vitreous luster. With increasing metamorphism they become definitely crystalline and individual grains of quartz can be made out with the hand lens. Even with intense dynamic metamorphism and crystallization they rarely lose their dense homogeneous appearance. They often take on a somewhat resinous luster due to the development of secondary minerals such as biotite, hornblende, and garnet. Near igneous contact the bedding is often obliterated and the rocks become coarse-grained aggregates of quartz with minor amounts of biotite and hornblende and resemble quartzites.

There is no gradation between the dense quartzose layers and the thin partings of slate or schist: the two are always sharply separated and evidently represent two distinct types of sediments, one highly siliceous, and the other somewhat argillaceous. In color they are white, gray, bluish or greenish gray, greenish or brownish black or black. They often weather brown due to the oxidation of their iron content.

Under the microscope the dense siliceous beds are seen to be made up of a mosaic of quartz grains with small amounts of secondarily developed minerals. Quartz is the most abundant constituent and makes up from 80 to 95 percent of the rock. Other minerals which have been recognized are garnet, biotite, green hornblende, muscovite, albite, apatite, pyrite, magnetite, hematite, and rutile. The garnets are always exceedingly small, rarely being more than 0.16 mm in diameter. They occur as individual grains, as trains of grains, and in small clusters or nests. They are usually interstitial but sometimes occur within quartz grains, or in biotite or hornblende. Biotite is a common constituent, sometimes making up as much as 12 percent of the rock. Biotite and hornblende rarely occur together in the same rock, but the garnets are ubiquitous. Albite occurs infrequently and has only been certainly determined in the vicinity of igneous contacts where soda may have been introduced by the granite.

Pyrite and magnetite occur sparingly as small grains, usually making up less than 1 percent of the rock; pyrite is perhaps slightly more abundant than the magnetite. Small specks of a reddish iron oxide, probably hematite, are common. Sometimes the individual quartz grains contain numerous minute unoriented needles, which appear to be rutile.

The texture of the rocks is characteristically mosaic, consisting essentially of small individuals of quartz of approximately the same size. The grain varies from 0.05 to 0.25 mm in the dynamically metamorphosed rocks, but is much coarser in those that have been affected by contact action. The secondary minerals are evenly distributed and have apparently been formed from impurities present in the original siliceous rock.

The following description of such a rock from southern Fresno County, a few miles northwest of Dunlap P. O., is typical of these rocks as a whole. This occurs about  $\frac{1}{2}$  to  $\frac{3}{4}$  of a mile from a granite contact and has been only slightly affected by contact action.

In the hand specimen this rock is seen to be essentially of quartz, so finely crystallized that the individual grains can only occasionally be made out with the hand lens. In color it is dark gray to brownish and greenish gray with a resinous luster. On weathered surfaces it is sometimes lightly filmed with black manganese oxide or with brown oxide of iron.

In thin section the microscope shows it to be a fine mosaic of quartz grains with minor amounts of garnet and a pleochroic green amphibole (green horn-



blende). The percentage composition of the rock as determined by a series of measurements is as follows:

	<i>Percent</i>
Quartz -----	86.0
Garnet -----	8.0
Green hornblende -----	5.5
Pyrite, magnetite, and apatite -----	0.5
	<hr/> 100

Thus silica would be approximately 92 percent. The texture is typically mosaic, the boundaries of the quartz grains never being sutured and only rarely crenulated. Most of the garnets occur interstitially but a few small individuals are included within quartz grains. It occurs as single grains but more commonly as irregular aggregates or in trains of grains. The green hornblende occurs as interstitial prisms and plates, often including garnet. The crystalloblastic order is garnet, pyrite, quartz, green hornblende. The garnet grains vary from .01 mm to .12 mm in size and average about .08 mm. The quartz mosaic is fairly even-grained, the individual grains averaging less than .20 mm. Frequently the individual grains show undulatory extinction. No indications of an original cementing material could be made out. The rock has evidently resulted from the crystallization of an almost pure silica rock such as a chert. This is also in accord with the silica percentage.

In general the garnets predominate over the biotite or hornblende, in some cases almost to the exclusion of the latter minerals, a quartz-garnet rock being the result.

With a combination of dynamic and contact action these rocks become coarser grained, with grains of quartz and crystals of garnet up to 1 mm in diameter. The original bedding becomes highly contorted and its sharpness is lost to a certain extent. It is not entirely obliterated and is represented by a distinct banding of the constituents. The thin partings, originally shaly, are converted into quartz-biotite and quartz-muscovite schists which merge into the purer quartz layers.

The least metamorphosed of these rocks naturally give the clearest evidence as to their origin. These are dense, often flint-like rocks which, even in the least metamorphosed areas, are thoroughly crystallized to an exceedingly fine mosaic of quartz, or of quartz and chalcedony, with much finely divided iron oxide. Small clear spots of more coarsely crystalline quartz free from interstitial iron oxide are frequently present. Although crystallization has been so thorough as to obliterate all traces of organic structure these spots without doubt represent skeletons of Radiolaria, the silica of the skeletons having crystallized as quartz. In the Mesozoic cherts all gradations may be observed between such spots showing traces of organic structure and those that have been completely crystallized. The red Arlington (Calaveras) cherts of Plumas County, in the extreme northern part of the range, show similar spots as do the red cherts of the upper part of the Calaveras, previously mentioned.

These cherty and quartzose rocks have previously been referred to as quartzites (representing sandstones) and as siliceous replacements of limestones. Neither of these hypotheses is substantiated by a careful examination of the rocks in the field and under the microscope.

The chief objection to their representing sandstones and shales is the fineness of grain and purity of the siliceous bands, most of which contain more than 90 percent of quartz. The exceedingly fine-grained flinty rocks are obviously not quartzites and there is no difference in the field relations and mode of occurrence of the flinty and more thoroughly crystalline types. The sharp separation of the schist and quartzose bands, while not conclusive, strongly indicates that they were not originally sandstones and shales since thin bands of exceedingly pure quartz sand separated by partings of shale are not common. In such cases the

sand, especially as the shale parting is approached, usually contains more or less intermixed argillaceous material. Moreover, the sandstones and the quartzites, which are clearly derived from sandstones, are not pure but contain relatively large amounts of feldspathic and ferromagnesian constituents. There is nothing in the general character of the Calaveras to indicate that chemical weathering, which might give rise to relatively pure quartz sandstones, prevailed in the area from which the sediments were derived.

In most cases these cherty rocks have previously been considered as siliceous replacements of limestone, an hypothesis which finds little support when all of the field relations are considered. Limestone lenses showing no sign of replacement are not infrequently in close proximity to these cherty rocks, sometimes within only a few feet. Also the cherty rocks may be followed for long distances along the strike without encountering any residual limestone bodies or without any final gradation into limestone. The writer has followed individual belts of such rocks for several miles and has visited many localities on such belts over a length of more than 20 miles without noting any evidence of limestone replacement.

Replacement of some of the limestones by silica has taken place to a certain extent but this is always local. The resulting rock is dense and homogeneous and is usually made up of chalcedonic silica. It is dark-colored and flinty and never shows any indication of bedding. In general, when a fossiliferous limestone is silicified the fossils are replaced by the silica without loss of organic structure. No such silicified fossils have been found in the cherts described above.

Even should the evidence offered by the clear spots of finely crystalline quartz, so suggestive of radiolarian remains, be disregarded, there seems to be no escape from the conclusion that these rocks are metamorphosed cherts and shales and that they represent original chemical sediments.

If the changes due to metamorphism, such as extreme contortion, thorough recrystallization, and loss of color, be disregarded, the mode of occurrence of these rocks is essentially the same as that of the varicolored Mesozoic cherts of this region and of the red radiolarian cherts of the Franciscan-Knoxville group in the Coast Ranges. All show the same remarkable rhythmic bedding and the same sharp separation between chert and shale. Also thicker lenses of more massive chert showing no shale partings are of frequent occurrence. The cherts of all three of these groups are not uncommonly lightly filmed with manganese even at a considerable distance from any known manganese deposit. Both the Mesozoic cherts of the Sierra Nevada and the Franciscan cherts of the Coast Ranges when metamorphosed pass into granular quartz rocks similar to the cherts of the Calaveras. These metamorphosed Calaveras cherts might best be referred to as "meta-cherts", the prefix indicating their present condition.

The meta-cherts of the Calaveras are nearly always closely associated with green schists derived from volcanic rocks.

#### Manganese Deposits of the Calaveras

Thirty-eight manganese deposits in the Calaveras group were visited. These occur in practically every county, from Fresno on the south to

Plumas on the north. Most of these deposits are extremely small and have never been developed; ore has been shipped from only nine of the Calaveras deposits, and of these only five have shipped more than 100 tons.

*Counties in which Calaveras deposits occur*

<i>County</i>	<i>Number of deposits visited</i>	<i>Number of deposits from which ore has been shipped</i>
Amador -----	5	3
Calaveras -----	8	-
El Dorado -----	1	-
Fresno -----	4	-
Madera -----	2	-
Mariposa -----	3	-
Nevada -----	1	1
Placer -----	3	2
Plumas -----	8	3
Tuolumne -----	3	-
Total -----	38	9

Deposits have also been reported from Tulare and Kern Counties but these were not visited. Undoubtedly many other deposits exist, but owing to the usual lack of deep oxidation and the presence of rhodonite and spessartite practically at the surface there has been little hope of reward to stimulate the search for ore in this region.

A description of each deposit visited would entail a needless amount of repetition that would serve no purpose in the present paper. Therefore, only the general results obtained from a field and microscopic study of the ore and associated rocks will be presented, with such detailed descriptions of certain deposits as are necessary.

The deposits that occur in the comparatively little-metamorphosed red radiolarian cherts of the Calaveras are in every way similar to most of those in the Amador and hence a description of the latter will be sufficient. Like the Amador cherts the red radiolarian cherts in the Calaveras are associated with basic volcanics in various stages of metamorphism. In some places the later Calaveras red cherts are directly associated with basalts that show well-developed pillow structure. The unmistakable red radiolarian cherts of the Calaveras occur in the Clipper Gap formation in Placer and Nevada Counties.

All of the Calaveras deposits that occur in association with meta-cherts either are in the more massive chert lenses intercalated in a series of thin-bedded meta-cherts, or in single massive lenses interbedded in phyllites or schists. The manganese ore occurs as lenses or beds which are always parallel to the bedding of the meta-cherts. Oxidation, the migration of the oxidized material, quartz-veining, and crushing and faulting often locally obscure the relations of ore to chert, but where the unoxidized material can be found it is always parallel to the bedding of the enclosing rock. Oxidation has usually been comparatively shallow and in nearly every case the material from which the oxide is derived may be observed. This material consists of manganese carbonate, partially recrystallized manganiferous opal, rhodonite, a manganese garnet, probably spessartite, and very minor amounts of other manganese minerals such as manganiferous amphibole. These minerals, either singly or together, are always found as kernels or cores surrounded by black

oxide near the lower limit of oxidation and as definite beds or layers below the zone of oxidation. In places where denudation has kept pace with or outstripped oxidation these primary minerals are found directly at the surface.

The "primary manganese minerals" are those from which the black oxide ores have been derived and are not necessarily the form in which the manganese was originally deposited. The term "original material" is reserved for these unaltered substances. Many of the primary minerals have been formed by the metamorphism of the original material.

It is believed that the manganese was originally deposited as a chemical sediment, in the form of the carbonate or as a manganiferous silica gel, or colloid, or often as an intimate mixture of the two, and that the denser silicates have been formed by the metamorphism of these substances.

The deposition or precipitation of these original substances and of silica apparently went on simultaneously and the three are intimately associated. In many cases the carbonate is intimately mixed with silica, sometimes as definite bands of carbonate and chert, and sometimes as an almost homogeneous mixture. Silica, being by far the most abundant, formed extensive beds of chert; the less abundant manganese formed smaller more local beds or lenses within the chert. In some cases thick beds of manganese carbonate containing little silica or manganese-silica gel were formed, but usually all three are present.

This concept of the origin of much of the manganese in this region is not the result of a study of the Calaveras deposits alone, but has been reached by a study of the lower Mesozoic deposits of this region and of the Franciscan deposits of the Coast Ranges, all of which are syngenetic deposits having a similar origin. All of the Calaveras deposits have been strongly metamorphosed but some to a lesser degree than others, so that in describing these deposits the degree of metamorphism may be used as a rough basis for division; the least metamorphosed deposits, where the associated rocks have reached the slate-phyllite stage, will constitute one division; another will include the more strongly dynamically metamorphosed deposits, where the associated rocks have been converted into schists; the third division will include those deposits directly affected by contact action.

No sharp line can be drawn between these types, especially between the first and second. Also it is difficult, if not impossible, to separate the effects of intense dynamic action from contact effects, and the second and third groups show many features in common.

In the less metamorphosed deposits the original materials, though recrystallized, may yet be distinguished. These are in all cases gray to pale pink manganese carbonate and a yellow to brown manganiferous opal, usually recrystallized to various hydrous manganese silicates. This latter material, in thin section, ranges from pale yellow to deep brown in color, is perfectly isotropic when unchanged, but crystallizes into fibrous manganiferous silicates showing the same range of colors as the unaltered material. The index of refraction is variable and ranges up to 1.595 in the more strongly colored varieties. The color and the refractive index very probably depend on the manganese content. When small fragments of the opaline material are treated with hydrochloric acid the manganese is completely removed leaving a coherent mass of

white opal which retains the outward form of the original fragment. The manganese is less easily removed from the hydrous manganese silicates. The nature of this type of ore has been discussed in the paper on the deposits of the Coast Ranges by F. S. Hudson and the writer and need not be described in detail here except to say that, in the Coast Range, this type of material frequently contains Radiolaria and is obviously a syngenetic deposit.

The manganiferous opal and its alteration products, the yellow to brown fibrous hydrous manganese silicates, occur with fine-grained carbonate in the less altered Calaveras deposits. Sometimes the two are banded, sometimes intimately mixed, and sometimes irregular areas of one occur in the other. Silica, in the form of bands of chert, or as disseminated grains of quartz or fibers of chaledony, is always present.

Metamorphism, even in its less advanced stages, has resulted in the formation of rhodonite and manganese garnet with minor amounts of other manganese-bearing minerals. Even under intense metamorphism the original bedding of the rock is not destroyed and bands or lenses of rhodonite and garnet representing the original material alternate with or occur in bands of almost pure quartz rock representing the original cherty layers. The ratio between all these constituents varies widely and many minor rock types result.

#### Characteristic Deposits

Descriptions of some of the more characteristic deposits and the relations between these various constituents will be given, the less altered deposits being first considered.

*M-Q Claim, Mariposa County.* The M-Q claim is located on Indian Gulch about a quarter of a mile west of its junction with the North Fork of Merced River, Sonora quadrangle.

The country rock is a dark blue-gray to black phyllite containing small lenses and layers of meta-chert with occasional more massive lenses. The ore is associated with one of these more massive lenses of meta-chert and occurs in the form of bands and stumpy lenses within the chert, the bands and lenses being always parallel with the bedding of the country rock. Amphibolite schists are present nearby.

Oxidation has been superficial and has extended inward from the surface and along cracks to a depth of 6 or 8 inches at most.

The unoxidized ore varies considerably in character. The prevailing type is a very dense pink to gray or fawn-colored manganese carbonate-rhodonite rock containing scattered grains of manganese garnet. Another type consists of bands of spessartite in meta-chert. A partial analysis of the manganese carbonate-rhodonite rock gave the following percentages:

MnO	-----	45.1
SiO <sub>2</sub>	-----	31.8
CO <sub>2</sub>	-----	18.5
		<hr/> 95.4

A recalculation of this analysis gives:

Manganese carbonate	-----	48.4
Rhodonite	-----	45.8
Quartz	-----	1.2
		<hr/> 95.4

Under the microscope the primary ore consists essentially of manganese carbonate with varying amounts of yellow to brown hydrous manganese silicates and some secondarily developed rhodonite and spessartite and a few small grains of quartz. The carbonate is exceedingly fine-grained, averaging less than 0.04 mm. The yellow to brown material occurs in small patches scattered through the carbonate, usually in fairly definite bands, layers of almost pure carbonate alternating with layers of mixed carbonate and fibrous hydrous manganese silicates. The original material of this deposit seems to have been largely carbonate and the secondarily derived silicate to be rhodonite; garnets are not abundant.

*American and Crown Point Mines, Placer County, and Black Ledge Mine, Nevada County.* These deposits, located about 9 miles apart, occur in the Cape Horn formation of the Calaveras group.

The unoxidized ore at these mines is of two types, one a very siliceous manganese carbonate-rhodonite rock, and the other a dense garnet-quartz rock. The former is a dense gray rock resembling a siliceous limestone except in its specific gravity. This gray fine-grained carbonate often shows irregular greenish or pink to light rose patches, which, under the microscope are seen to be rhodonite, albite, and quartz in varying proportions. The rock is largely very fine grains and rhombs of cloudy brownish manganese carbonate, patches of fibrous brown hydrous manganese silicates with small amounts of rhodonite, spessartite, albite, and quartz. Garnets occur as minute grains chiefly in the patches of hydrous silicates, but also through the carbonate. The rhodonite occurs in moderately large irregular grains or as bladed prisms. Minute garnets are sometimes so abundantly included in the rhodonite as to give a sieve texture. Veinlets of more coarsely crystalline manganese carbonate and rhodonite are numerous. In some parts of these deposits the conversion of the original materials into rhodonite and garnet has been almost complete, a rhodonite-garnet-quartz rock, with only small residual patches of carbonate, being the result.

The dense garnet rock consists almost wholly of exceedingly fine-grained garnets, a few residual patches of hydrous manganese silicates, and minor amounts of quartz. The densely packed garnet grains average less than 0.01 mm in diameter, and in some cases apparently merge into almost massive garnet rock.

*Deposits of the Murphys District.* There are several manganese deposits within a radius of 4 miles of Murphys, a small town in Calaveras County, 8 miles northeast of Angels Camp. All of these are of the same type and mode of occurrence, all being in meta-cherts and schists of the Calaveras group.

The schists in which the deposits occur are nearly all very siliceous, but chloritic and amphibolitic schists are present. A belt of meta-cherts extends through this region, and in this belt the manganese deposits occur, in the more massive chert lenses intercalated in the thin-bedded meta-cherts and schists.

All of these deposits are small and of little economic importance and none have been developed to any extent. However, the primary minerals occur at the surface and the nature of the deposits may be readily made out in spite of the lack of development work.

In nearly every case the unoxidized material consists of light-brown manganese garnets which pass into a dusty, crumbly black to brownish-black manganese oxide. Rhodonite was found in only one prospect where it occurred as small grains and as minute bladed crystals associated with spessartite and quartz. No trace of the original material from which the manganese garnets were derived could be found.

The garnets occur as definite bands and lenses parallel to the bedding of the meta-cherts. These lenses are usually only a fraction of an inch to a few inches in width, but a few were seen which were as much as 3 feet in width and 15 to 20 feet in length. Sometimes these lenses are almost wholly of closely packed garnets, but usually the garnets are scattered through a very fine-grained mosaic of quartz grains. Elliptical areas, up to an eighth of an inch in diameter, of radiating fibers of a slightly manganiferous brown to yellow-brown amphibole occur here and there through these quartz-garnet rocks.

*Deposit in Southern Fresno County.* Thoroughly crystalline banded siliceous rhodonite-garnet-quartz rock occurs in southern Fresno County, about 27 miles east of Sanger. No development work has been done here but oxidation has been superficial and practically unoxidized material occurs at the surface. The manganese minerals are in a massive lens of meta-chert 1 to 3 feet thick intercalated in thin-bedded meta-cherts and quartz-mica schists. Bands of rhodonite-garnet rock alternate with dense fine-grained layers of meta-chert, the individual layers ranging from a fraction of an inch to several inches in thickness. Microscopic as well as megascopic banding occurs, and a single thin section often shows a number of definite bands.

In thin section quartz, rhodonite, spessartite, a slightly manganiferous fibrous amphibole, and fine granular manganese carbonate may be recognized. The rock is distinctly banded, the bands consisting of quartz with only scattered grains of garnet or rhodonite alternating with layers of garnet or rhodonite or both. The manganese silicate bands are usually much smaller than the quartz bands but one thin section shows a fairly large, somewhat stumpy lens which is wider than most of the quartz bands.

The manganese carbonate occurs only within the larger manganese silicate bands. It is an exceedingly fine-grained aggregate, in which are embedded scattered grains of garnet and rhodonite, and probably represents original manganese carbonate, a small amount of which still remains unconverted into the silicates. It is never closer than about half a millimeter to quartz, being always separated from the latter by a rim of rhodonite or garnets. This may give a rough measure of the distance through which manganese carbonate and silica can combine to form a manganese silicate.

Although distinctly banded the most pronounced characteristic of the rock as seen under crossed nicols is a mosaic texture. Except for the bands of manganese minerals this rock differs not at all from the barren meta-cherts. Thin sections of both show the same size of grain, less than 0.2 mm. The manganese silicate bands evidently represent original layers or lenses of manganese carbonate in chert.



### Contact-Metamorphosed Deposits

Several deposits at or near granitic igneous contacts were visited but unfortunately no deposit could be traced along the strike from a part showing only dynamic metamorphism to the actual contact. However, little or no material has been introduced from the igneous rock and the difference between an intensely dynamically metamorphosed and a contact-metamorphosed deposit is one of degree rather than of kind.

The best example of this type of deposit is located in Watts Valley in north-central Fresno County. The actual contact is obscured by a heavy mantle of alluvium but a 40-foot shaft sunk near it has exposed the products of the metamorphic action.

The metamorphosed sedimentary rocks are exposed along a low ridge and may be traced to within about 150 yards of the actual contact. The most distant exposures are about 450 yards from the contact and even these show marked effects. A thickness of 300 to 350 feet of metamorphosed sedimentary rocks is exposed on the low ridge; these rocks consist of quartz-mica schists, coarse quartz schists, quartz-rhodonite schists, quartz-calcite schists and crystalline limestone. The massive quartz rocks are interbedded with banded quartz schists and mica schists and seem to represent a highly metamorphosed massive chert in thin-bedded cherts and shales. The quartz-rhodonite rock occurs as lenses in one of these more massive quartz rocks and can be traced almost continuously along the strike throughout the exposed length of the rocks, a distance of about 300 yards. These are associated with quartz-mica schists and quartz-mica-calcite schists containing lenses of limestone up to 10 feet in width and 60 feet in length; as shown by the limestone lenses the schistosity is parallel to the original bedding. The crystalline limestones contain numerous patches and nests of fine-grained wollastonite even at a distance of 400 yards from the contact. Amphibolitic schists are interbedded with the quartz-mica schists.

At the contact the changes are striking. A small pit has been opened on the limestone horizon and coarse-grained garnet-vesuvianite rocks are exposed, which represent the extreme metamorphism of the limestone. Fine-grained plagioclase-pyroxene gneisses or hornfels have been formed from the amphibolitic schists. These rocks are dense and granular and greenish to faintly purple in color; under the microscope they are found to consist of a granular pyroxene, either augite or diopside, and laboradorite-bytownite in about equal proportions with minor amounts of sphene and a few grains of calcite. Scattered grains of magnetite, prisms of apatite, and crystals of garnet also occur.

About 400 feet south of this pit is a small outcrop of very resistant rhodonite rock a few feet in extent. Here a shaft has been sunk almost on the contact. This shaft has partially caved and little can be learned from it. However, the rocks on the dump show the effect of the contact metamorphism of the manganese deposit. Coarse-grained, tough, rose-pink rhodonite rock is the chief product and this is often banded with quartzose layers containing grains of manganese garnet, some rhodonite, a manganiferous amphibole, and diopside.

In thin section the rhodonite rock is seen to consist of interfering plates and grains of rhodonite without definite crystal outline, and grains and small patches of spessartite. Quartz always is present but in varying amount, sometimes as only occasional grains, but often as one of the chief



constituents. The more quartzose layers are made up of a fine mosaic of quartz grains in which are embedded manganese garnets and small grains of diopside. This mosaic is interrupted by large plates of greenish manganese hornblende and granular aggregates of hornblende and diopside. The large hornblende plates often poikilitically include grains of garnet and pyroxene which are sometimes so numerous as to give a sieve-like texture. Apatite is fairly abundant and occurs as small stout prisms in the quartz. Feldspar is rare, only a few grains of almost pure albite being observed.

The crystalloblastic order is apatite, garnet, diopside, manganese hornblende, and quartz.

Injection rhodonite gneisses have been formed by the penetration of thin tongues of granitic material between the rhodonite and quartzose layers. These thin tongues, rarely over 5 or 6 mm in width, consist of quartz, andesine ( $\text{Ab}_{60}\text{An}_{40}$ ), pale green hornblende, sphene, small prisms of apatite, and manganese garnets. The garnets and hornblende become especially abundant near the contact. Usually there is a 1 to 2.5 mm band of hornblende-garnet rock containing only minor amounts of feldspar and quartz along the contact.

There is no evidence that the manganese has been introduced by the granite. The rhodonite rock a quarter of a mile from the granite is essentially the same as that at the contact. The only effect of the contact action has been a marked increase in grain and the development of diopside and large crystals of manganese hornblende in the more quartzose layers.

Two other contact-metamorphosed Calaveras deposits, one in southern Madera County, the other in central Tuolumne County, just west of the town of Tuolumne, were found. Both of these occur in small roof pendants of siliceous schists embedded in large granitic stocks. These show the same development of rhodonite rock alternating with bands of quartz-spessartite rock occasionally containing rhodonite. A fibrous amphibole has been developed in the more quartzose bands in both of these localities.

#### The Rhodonite-Spessartite-Quartz Rocks

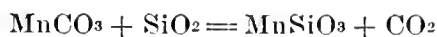
The three most important minerals formed by the metamorphism, either contact or dynamic, of the Calaveras manganese deposits are rhodonite, the manganese pyroxene, a manganese garnet, probably allied to spessartite, and quartz. Although other minerals are present these three make up fully 95 percent or more of the various metamorphosed deposits and it is from the manganese silicates that most of the commercial black oxide ores have been derived.

#### Origin

From the brief descriptions given of some of the more characteristic deposits it is clear that the least metamorphosed are made up of manganese carbonate and fibrous hydrous manganese silicates with varying amounts of the secondarily formed silicates, rhodonite and spessartite. The manganese pyroxene and manganese garnet develop from the manganese carbonate and hydrous manganese silicates in the same manner as wollastonite and lime garnet develop from a siliceous limestone. Rhodonite appears to develop chiefly from siliceous manganese carbonate or

from the mixed manganese carbonate-manganiferous opal ores (see *Genesis of the Manganese Deposits of the Coast Ranges of California*, by N. L. Taliaferro and F. S. Hudson, this bulletin), while the manganese garnet appears to form chiefly from manganiferous opal.

Under heat and pressure the carbonate breaks down and unites with silica and other impurities present to form manganese silicates. If manganese carbonate and silica only are present, pure rhodonite will form according to the following reaction, which involves no change in the state of oxidation of the manganese:



No analyses of the Sierra Nevada rhodonites have been made and the possible percentages of other oxides such as FeO, CaO, and MgO are not known. However, rhodonite usually contains a small amount of iron and lime and it is quite probable that the rhodonite from this region is not an exception to the general rule. Very small quantities of such impurities then would probably go into the rhodonite. If, in addition to silica, alumina, iron, lime, and magnesia are present as impurities, a manganese garnet will form. Various reactions might be written showing the formation of the garnet but since the actual composition of the garnet is not known these would be of little value.

There is good evidence that the rhodonite and spessartite garnet form in this manner. In the less metamorphosed deposits these minerals occur as patches through the carbonate and siliceous carbonate rocks. With increasing metamorphism these become more abundant and finally all trace of the original carbonate disappears, if sufficient silica and other impurities are present to combine with it, which is usually the case.

Although the rhodonite and spessartite are closely associated they have a very distinct mode of occurrence. While garnets are always present in the rhodonite rocks they are rather infrequent, especially in the almost quartz-free rhodonite rocks. As quartz becomes more abundant the garnets also increase in number. In the typical quartz-spessartite and spessartite rocks rhodonite is almost entirely lacking. This gives rise to certain well-defined types which may be listed as follows:

<i>Without quartz</i>	<i>With quartz</i>
Rhodonite rock	Quartz-rhodonite rock
Rhodonite-spessartite rock	Quartz-rhodonite-spessartite rock
Spessartite rock	Quartz-spessartite rock
	Quartz rock (meta-chert)

This classification might be amplified almost indefinitely by considering the other constituents which are often present. These consist of residual manganese carbonate, manganiferous opal and hydrous manganese silicates derived from the opal, and of various newly formed minerals among which are manganiferous amphibole, diopside, biotite, albite, apatite, magnetite, and pyrite. These are usually present in only small amounts and may be omitted.

All of the rocks listed above may, and usually do, occur in the same deposit. They frequently occur in alternate bands often on a very fine scale, though larger beds of each may occur.

**Rhodonite-Spessartite Rock**

This is more closely related to rhodonite rocks than to true spessartite rocks, rhodonite usually predominating over garnet. It is not a very distinct type as all gradations exist between it and rhodonite, quartz-rhodonite, and quartz-rhodonite-spessartite rocks.

**Spessartite Rock**

This constitutes a very definite type, of which there are several minor varieties. Typical spessartite and quartz-spessartite rocks rarely contain rhodonite.

The most usual type is a medium to fairly coarse-grained rock consisting almost wholly of garnets but occasionally containing a small amount of biotite and fibrous amphibole; grains of quartz are usually present. Individual garnets nearly always show good crystal outline, especially in the coarser-grained rocks. In color these vary from a pale yellow-brown or brownish-yellow to brownish-red or a clear wine-red.

Less commonly these rocks are exceedingly dense and compact and resemble, except in specific gravity, a dense chert. In color they vary from a dull gray to brown, and often have a waxy luster. So dense and fine-grained are they that individual grains cannot be distinguished with the hand lens.

Thin sections show them to be made up of closely packed, minute grains of garnet rarely more than 0.05 mm in diameter. Within this fine-grained aggregate are occasional areas of massive structureless, perfectly isotropic garnet. There is a rapid gradation from the grained portions into these structureless areas, the grain becoming finer until all sign of crystal outline is lost.

Here again the degree of metamorphism and the size of the grain are closely related. The fine-grained type occurs in the less metamorphosed deposits where the enclosing rocks have barely passed the phyllite stage. The coarser-grained types occur in crystalline schists.

**Quartz-Spessartite Rock**

The typical spessartite rock generally occurs as bands of varying thickness in quartz-spessartite rock or in almost pure quartz rock. These bands vary from a small fraction of an inch to as much as several feet in thickness. Typical quartz-spessartite rock consists of small euhedral garnets in a quartz mosaic, the garnet crystals and the quartz grains being about the same size. The grain of the rock varies from 0.06 or 0.07 mm to as much as 1 or 2 mm in the contact-metamorphosed deposits; usually it is under 0.2 mm. The ratio between quartz and spessartite varies widely but they are commonly in about equal proportions. In addition to the quartz and garnet these rocks usually contain a fibrous yellow to brown manganiferous amphibole, generally as radiating fibers in the quartz mosaic. Small prisms of apatite are commonly present and flakes of a yellow to red brown strongly pleochroic biotite sometimes occur. Magnetite and pyrite are usually sparingly present in grains. Albite is infrequent but has been observed in two cases.

Rocks of this type are commonly banded with practically pure rhodonite rock, in fact, no deposit made up exclusively of rhodonite has been found. However, deposits consisting wholly of spessartite and

quartz-spessartite rocks are not uncommon. It may be definitely stated that garnets are always present even in almost pure rhodonite rocks but that rhodonite practically never occurs in spessartite rock or in typical quartz-spessartite rock. The significance of this fact is obvious. Garnets will form if small amounts of alumina, iron, and calcium are present but rhodonite will not form if these impurities exceed a certain amount. This amount is not known but it is probably under 15 percent.

Regarding the occurrence of spessartite in contact zones Tilley<sup>15</sup> states:

"When the garnet of garnet-bearing aureoles is shown to contain notable quantities of MnO, and when further such garnets are inconstant and sporadic in their occurrence (suggesting local concentration of the manganese), it would appear legitimate to conclude that the formation of garnet in pelitic aureoles is conditioned by the presence of MnO in the sediment, leading to the formation of a spessartine-bearing type."

That the garnets in the Sierra Nevada deposits contain notable quantities of MnO is shown by the fact that they oxidize to black manganese-oxide rocks, some of which contain a sufficient quantity of manganese to be classed as ores. The occurrence of the spessartite in roof pendants and contact zones is definitely "inconstant and sporadic" and not general throughout the zone. There is no evidence to indicate introduction of manganese from the plutonic intrusives.

#### Quartz Rock

This is simply a meta-chert. It occurs as bands separating the rocks just described, and as the massive lenses in which they occur. It sometimes contains small amounts of manganese garnet or rhodonite, or both, and in fact nearly all gradations may be traced from almost pure quartz rock to almost pure rhodonite rock or from quartz rock into spessartite rock. Its texture is typically mosaic. Rocks of this kind have been described under the meta-cherts of the Calaveras group.

#### Other Occurrences of Rhodonite-Spessartite-Quartz Rocks

Rocks that appear to be similar to the rhodonite-spessartite-quartz rock of the Sierra Nevada have been described from many parts of the world, particularly from Great Britain, Switzerland, the Ural Mountains, Finland, Italy, Japan, France, Spain, Brazil, Canada, and India.

Woodland<sup>16</sup> describes deposits in Wales that contain spessartite, rhodochrosite, rhodonite, and hematite, that are considered to be the product of metamorphism of syngenetic colloidal mangiferous sediments made up of manganese carbonate and clayey material.

There is a voluminous literature on the deposits in the vicinity of Roffna, Switzerland, particularly regarding the rare minerals found in the various mines. The most comprehensive account is that by Jakob,<sup>17</sup> who describes the occurrence, genesis, and mineralogy, but not the original nature of the ores. These deposits are similar in many respects to the Franciscan ores of the Coast Ranges and the Calaveras and Amador deposits of the Sierra Nevada, in that they always occur as lenses or layers interbedded with rhythmically bedded red radiolarian cherts and

<sup>15</sup> Tilley, C. E., On garnet in pelitic contact zones: *Min. Mag.*, vol. 21, p. 50, 1926.

<sup>16</sup> Woodland, A. W., The petrography and petrology of the Lower Cambrian manganese ore of Merionethshire: *Geol. Soc. London, Quart. Jour.*, vol. 95, pp. 1-35, 1939.

<sup>17</sup> Jakob, J., Die Manganerzlagerstätten zwischen Vol. d'Err und Roffna (Oberhalbstein), ihre Begleitminerale und ihre Genesis: *Schweiz. Min. Pet. Mitt.*, vol. 13, pp. 17-39, 1933.

shales; like the Amador and Franciscan deposits they are Jurassic. Jakob regards them as syngenetic with the enclosing cherts and shales; he refers to the cherts as "Das Muttergestein dieser Mangangerze." They have been intruded by quartz-rich igneous rocks and have suffered both contact and hydrothermal alteration, apparently with the complete obliteration of the original materials. According to Muller<sup>18</sup> they also have been intruded by serpentine. Rhodonite has been developed but the most abundant minerals are the rare hydrous aluminum-manganese silicates tinzenite, surassite, and parsettensite. These minerals also have been described from similar deposits in Italy.<sup>19</sup> None of them have been identified positively in the California deposits.

Stelzner and Bergeat,<sup>20</sup> in discussing sedimentary manganese deposits give as one of their five groups "deposits of manganese oxide originating from rhodonite and mangankieselschiefer." Under this group they briefly describe deposits from the Ural Mountains, Italy, Spain, and other parts of Europe; many of these are associated with cherts.

Rhodonite-spessartite-quartz rocks occur as lenses in metamorphosed Paleozoic sediments in the French Pyrenees.<sup>21</sup> Although the associated rocks are not described these appear to be similar to some of the Calaveras deposits.

The manganese deposits of the Huelva district, Spain, below the oxidized zone, are made up of rhodonite and manganese carbonate lenses in cherts. According to Johnson<sup>22</sup> they occur as "fissure fillings in gray, brown, and red jasper" but Hoyer<sup>23</sup> interprets them as metamorphosed syngenetic deposits. They appear to be very similar to many of the Sierra Nevada deposits, as the ore lenses occur in red cherts that are interbedded with slates and schistose volcanic rocks.

Lenticular masses of rhodonite in "gneiss, sericite schist, quartzite, hornstone, radiolarian slate, and schalstein" of Paleozoic age is reported as occurring in 44 Japanese provinces.<sup>24</sup> Unfortunately no detailed accounts of any of these deposits has been given in any other language than Japanese.

Lenticles of diopside-rhodonite-spessartite-quartz rocks occur in "quartzites" in Finland.<sup>25</sup>

Manganese deposits that appear to be very similar to those in the Sierra Nevada occur in the Courchan Lake area, Vancouver Island. According to Hanson<sup>26</sup> the deposits occur in the Vancouver volcanics, of Triassic or Jurassic age in well-bedded cherts and "jaspery" magnetite schists that are interbedded with the volcanics; as in the Sierra

<sup>18</sup> Muller, F. P., Die Manganerzlagerstätten des Oberhalbstein (Graubünden, Schweiz): Zeitschr. Prakt. Geol., vol. 24, pp. 219-228, 1916.

<sup>19</sup> Pelloux, A., Tinzenite e parsettensite della miniera di Casagna (Liguria orientale): Boll. Soc. Geol. Italiana, vol. 53, pp. 235-238, 1934.

<sup>20</sup> Stelzner, A. W., and Bergeat, A., Die Erzlagerstätten, pp. 240, 247-254, Leipzig, 1904.

<sup>21</sup> Thiebaut, L., Sur l'origine des gisements de minerais de manganèse des Pyrénées françaises: 7th Cong. Int. Mines, vol. 1, pp. 159-164, Paris, 1935.

<sup>22</sup> Johnson, Frank, The manganese deposits of Huelva, Spain: Inst. Min. and Met., Trans., vol. 3, p. 275, 1895.

<sup>23</sup> Hoyer, K. G., Beiträge zur Kenntnis der Manganerzlagerstätten in der Spanischen Provinz Huelva: Zeitschr. Prakt. Geol., vol. 19, pp. 407-431, 1911.

<sup>24</sup> Mining in Japan, Past and Present, Bureau of Mines, Dept. of Agriculture and Commerce of Japan, 1909.

<sup>25</sup> Hietanen, Anna, Über den Rhodonit und andere Mangan Minerale von Simsiö, Pohjanmaa: Comm. Geol. Finland, Bull. 115, pp. 387-400, 1936.

<sup>26</sup> Hanson, G., Manganese deposits of Canada: Canada Geol. Survey, Econ. Geol. Ser. no. 12, 1932.

Nevada, the rocks are intruded by granodiorite. Rhodonite is the chief mineral below the oxidized zone.

A detailed account of spessartite-rhodonite rocks has been given by Fermor<sup>27</sup> in his description of the manganese deposits of India. The rocks described by Fermor are practically identical with the more severely metamorphosed Calaveras deposits, except that they are much thicker than the Sierra Nevada deposits. In India these rhodonite-spessartite-quartz rocks occur in the Gondite series, a strongly metamorphosed phase of the Dhárwár series of "Transition" or Algonkian age. So characteristic is the spessartite-quartz variety that Fermor gives it a special name, "gondite" from the rocks in which it occurs. Using this name as a basis an entire group is built up, containing such rocks as rhodonite-gondite, amphibole-rhodonite-gondite, etc.

This nomenclature is satisfactory except that it introduces a new name and overemphasizes the importance of the spessartite-quartz rocks. Rhodonite and rhodonite-quartz rocks are quite as important, and, in the Sierra Nevada as well as in many other parts of the world, constitute a larger proportion of such metamorphosed deposits than the so-called "gondites." This being the case, the rhodonite-quartz series should be given a distinct name, which would lead to the introduction of one or more new rock names of doubtful value. It is believed that a mineralogical nomenclature, expressing the mineral composition of any particular rock, although cumbersome, is, in reality, simpler and more logical.

Fermor recognized the sedimentary nature of the Dhárwár manganese deposits but considered that the manganese was originally deposited as one of the black dioxide types and subsequently wholly converted by strong metamorphism into rhodonite and spessartite; no trace of the supposed original black oxides remain in the present primary ores below the oxidized zone, although the rhodonite and spessartite have been oxidized to the black oxides at the surface. There is no evidence for and much against such an origin for the Sierra Nevada and Coast Range deposits. Had the black dioxides been the original material the change in volume necessary for their conversion into carbonate, hydrous manganese silicates, manganiferous opal, and rhodonite, would have, for one thing, entirely destroyed the original fine banding. Other and more convincing proof that manganese dioxide was not the original material of the California deposits is presented in the paper by Taliaferro and Hudson on the Coast Range deposits in this bulletin.

Fermor describes red, gray, and black cherty quartzite which he considers to be metamorphosed quartz sandstones. From the description of the appearance and texture of these rocks the writer is inclined to the view that they are meta-cherts; the fact that Dhárwár manganese deposits always occur with such rocks is suggestive.

#### Amador Manganese Deposits and Associated Rocks

##### Introduction

A brief statement regarding the general nature of the Amador group already has been given but a more detailed description of the rocks directly associated with the manganese deposits is necessary. These

<sup>27</sup> Fermor, L. Leigh, The manganese deposits of India: India Geol. Survey, Mem., vol. 37, 1909.

rocks are similar in some respects to the Franciscan-Knoxville group of the Coast Ranges but there are certain notable differences.

The manganese deposits of the Amador, like those in the Franciscan always are associated with cherts, usually with red radiolarian cherts. Furthermore, the manganese deposits of both groups always are associated with the more massive and thicker chert lenses.

#### Contrast Between the Amador and Franciscan-Knoxville Groups

Although both groups contain rhythmically bedded radiolarian cherts and pillow basalts there is little similarity between them. In the first place, although both are Jurassic, the Amador is the older, being earlier than the Nevadan orogeny; deposition of the Franciscan-Knoxville group took place after this orogeny. The Amador is in a more advanced stage of metamorphism, having been subjected to strong folding and regional dynamic metamorphism, as well as to contact action on the margins of intrusive igneous bodies. There also is a very marked difference in the nature of the detrital sediments. The great bulk of the Franciscan is made up of coarse arkosic sandstones, whereas coarse detrital sediments are rare in the Amador, except in the basal beds. In fact even fine detrital sediment is not abundant in the Amador, except locally, usually being masked by more rapidly accumulating volcanics. The Amador is neither as thick nor as widely distributed as the Franciscan. Furthermore the Amador volcanics are, on the average, less basic than those of the Franciscan, being chiefly augite andesites and dacites; tuffs and agglomerates are more abundant in the Amador.

Both cherts and pillow basalts occur in the Amador but they are insignificant both in amount and stratigraphic and geographic distribution compared with those in the Franciscan. However, there is one continuous belt of chert and pillow basalt in the Amador fully as thick and as long as any in the Franciscan.

#### Amador Cherts and Associated Volcanics

The thickest and most continuous belt of chert in the Amador occurs in northern Mariposa and southern Tuolumne counties, where it has a length of 20 miles and a maximum thickness of 950 feet. This belt of cherts and tuffs is shown on the geologic map of the Sonora folio<sup>28</sup> and is the only instance in which any part of the Amador was mapped as a separate unit. The following statement appears in the text of the Sonora folio:

"There will be noted on the geologic map some bands of chert intercalated in the igneous rocks which lie between the eastern and middle belts of the Mariposa formation. These are presumed to be of Juratrias age, as they appear to have been formed during the period of the eruption of the porphyrites with which they are associated."

These cherts are shown on the geologic map of the Sonora folio as three discontinuous en echelon belts, having a total length of 12 miles, whereas they form one continuous belt 20 miles in length. They may be traced continuously from the south end of Hunter Valley, in Mariposa County, to a point northeast of Indian Bar, in Tuolumne County, where they are abruptly terminated by a large mass of serpentine. Similar

<sup>28</sup> Turner, H. W., and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Sonora folio (no. 41), 7 pp., 4 maps, 1897.



cherts occur both to the northwest and southeast but they are neither as thick nor as continuous as the Hunter Valley unit.

These cherts, which are a local unit of the Amador, have been named the Hunter Valley cherts by the writer.<sup>29</sup> Both the cherts, and the pillow basalts on which they rest, are on the eastern limb of a large faulted anticline; neither is repeated to the west because the eastern limb of the anticline has been thrust over the western limb and the cherts and basalts lie buried beneath the thrust.

The thickest section of both the pillow basalts and the Hunter Valley cherts is along and immediately south of Merced River where the basalts are 1200 feet and the cherts 950 feet in thickness. Both units become thinner to the northwest and southeast of the river. As the basalts thin, by a disappearance of individual flows, there is a corresponding thinning of the cherts. To the southeast, just above the head of Hunter Valley, the cherts continue as a very thin lens a few hundred yards beyond the point where the basalts end; on the northeast both are very thin where they are terminated by the serpentine. Thus, both cherts and pillow basalts have practically the same distribution. This close connection between, and coincidence in distribution of pillow basalts and radiolarian cherts also are characteristic of the Franciscan of the Coast Ranges. So close and so constant is the connection that the pillow basalts are regarded as the source of at least a part, if not all of the silica forming the cherts.

Both the cherts and the pillow basalts are a part of a thick volcanic sequence. The basalts overlies augite andesite flows, tuffs, and agglomerates, and the cherts grade upward into the same type of volcanics. The volcanics above the Hunter Valley cherts contain a few thin lenses of impure green cherts and siliceous mudstones.

Along the Merced River the cherts dip to the northeast at an average angle of about  $30^{\circ}$ ; toward the top of the section they steepen to  $65^{\circ}$ . The northeastward dip of the entire section increases both to the northwest and southeast of Merced River.

The basalt flows beneath the cherts have well-developed pillow structures throughout their entire extent. The pillows vary from a few inches to several feet in diameter and form the usual closely packed aggregate of ellipsoidal and irregularly rounded pillows so characteristic of such rocks throughout the world. Red and yellow jasper, often with a typical internal spheroidal texture, sometimes occurs in the spaces between the pillows. On fresh surfaces the basalt is a dense gray-green to dark-green rock that weathers to a rusty red-brown.

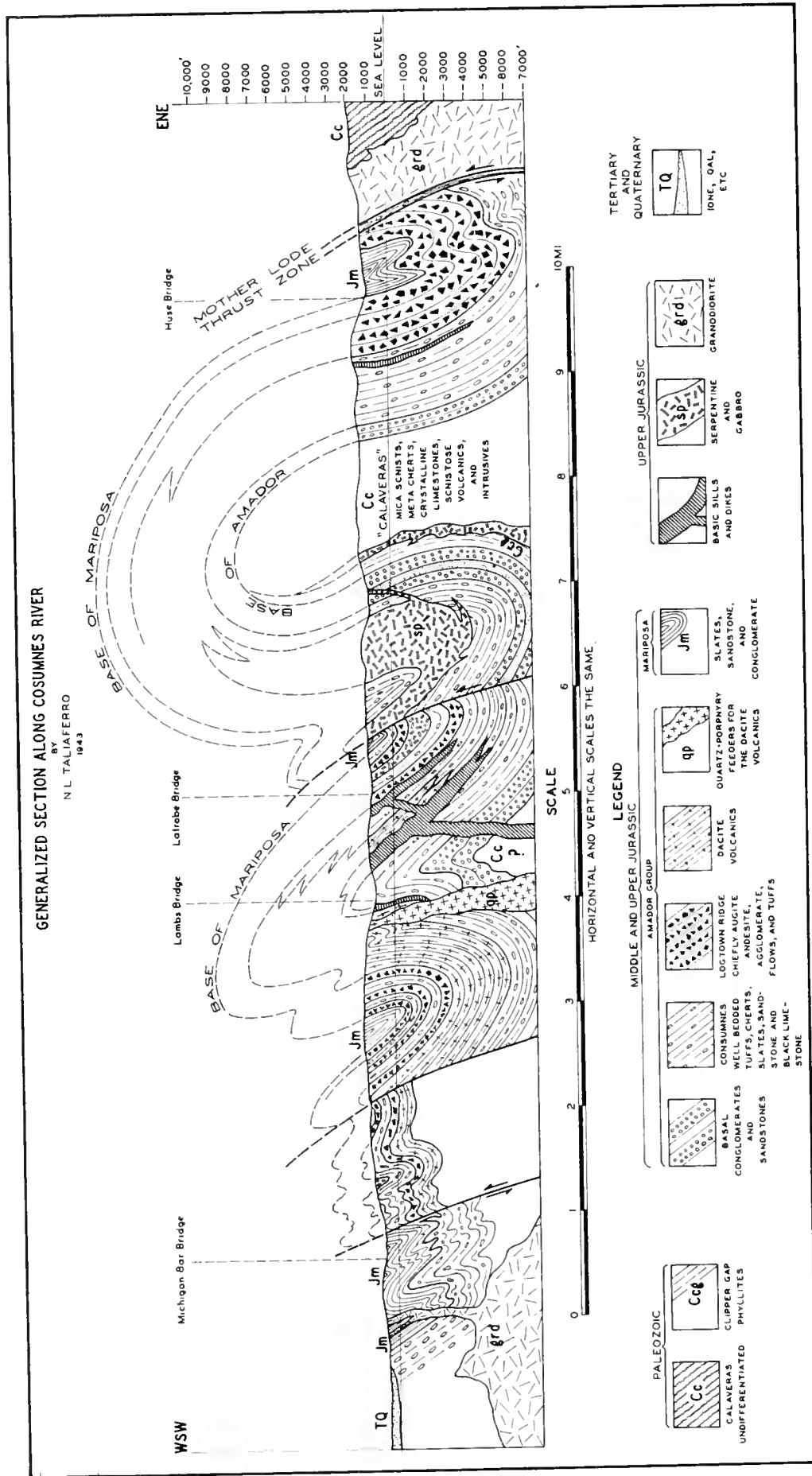
Under the microscope there is seen to be a slight variation in texture and average grain size of the individual flows, but there is only slight variation in mineral composition. Augite is the predominant mineral, being much more abundant than the plagioclase, which is usually altered. The augite occurs in two generations, the earlier being minute, well-formed phenocrysts, ranging up to 0.30 mm in length, the average being about 0.15 mm. The augite of the second generation occurs in sheaf-like, plumose aggregates, usually with a radial arrangement. These radial aggregates make up by far the greater part of the rock.

<sup>29</sup> Taliaferro, N. L., Bedrock complex of the Sierra Nevada, west of the southern end of the Mother Lode (abstract): Geol. Soc. America Bull., vol. 44, pp. 149-150, 1933.





Fig. 1. Rhythmically bedded meta-cherts of the Calaveras, on the road between Mokelumne Hill and Railroad Flat, Calaveras County. Nearby these are lightly stained with black manganese oxide.



**Fig. 2.** Geologic cross-section along the Cosumnes River, based on detailed work by N. L. Taliaferro. The section is greatly generalized to accommodate the scale; only the major folds and larger intrusions are shown. Examples: The syncline of Mariposa slate west of Lambs Bridge is compound and intricately folded. Only one quartz porphyry intrusion is shown just west of Lambs Bridge; actually there are many small intrusions. This section is shown for the purpose of comparing the geologic units employed by the writer with those of the earlier Sierran folios.

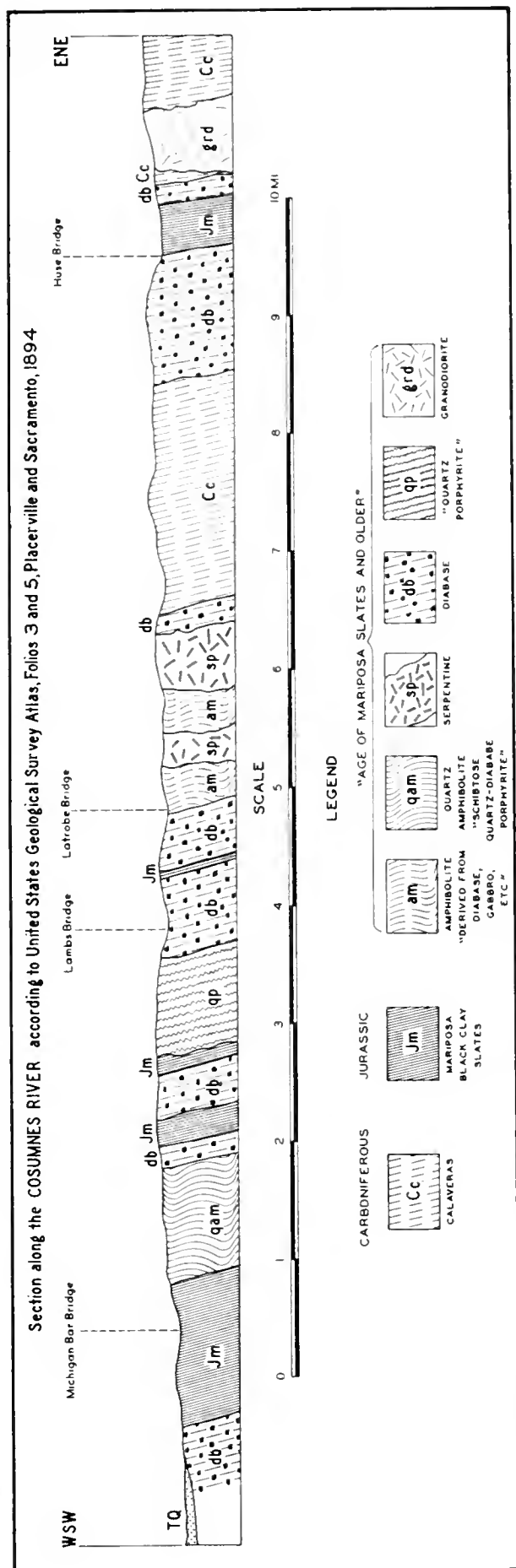


Fig. 3. Geologic cross-section along the Cosumnes River, based on the early work (1894) of the U. S. Geological Survey in Folio 3 (Placerville) and Folio 5 (Sacramento). This section is shown for the purpose of comparing the geologic units employed in the folios with the newly proposed units of N. L. Taliaferro.

#### EXPLANATION OF FIGURES 2 AND 3

After receiving proof of the accompanying paper, the writer was requested to present a typical cross-section of the lower slopes of the Sierra Nevada and to indicate graphically how the new geologic units (Cosumnes, Amador, and Logtown Ridge) he has proposed at various times correspond with those earlier shown on the Sierran folios of the U. S. Geological Survey. This has been done, but since not all of the new units are referred to in the writer's present paper, a brief explanation of the sections is necessary.

Both cross-sections are taken along the same line, along or close to the Cosumnes River. For ease of comparison the various bridges across the Cosumnes River are shown on both sections; these bridges are shown on the folios mentioned. It is believed that in this way the various units proposed by the writer may readily be compared with those shown on the earlier geologic maps of the Sierra Nevada.

A comparison of the two sections shows that a part of the Amador unit between Huse and Latrobe crossings was originally included in the Calaveras formation. The writer's basis of separation of the Amador in this region is the presence of a thick basal conglomerate containing abundant debris of the Calaveras, and the presence of Jurassic ammonites above the basal conglomerate.

Since much of the Amador is volcanic, and since there were several centers of volcanism, there is great lateral variation in lithology and thickness. Submarine centers, emitting chiefly augite andesites, lay to the east, and submarine centers of more acidic character lay to the west. The Logtown Ridge augite andesite agglomerates, 2700 feet thick at Huse Bridge, thin westward and pass into fine-grained augite andesite agglomerates and bedded tufts. The chief dacitic centers lay to the west of Lambs Bridge.

The augite andesite flows, agglomerates, and tufts, and much of the "Cosumnes" type of well-bedded tufts, cherts, limestones, and slates are included in the so-called "amphibolites" and "diabase" of the Sierran folios. However, not all of the amphibolites shown on the folios are of Amador (Jurassic) age, as there are wide belts of schistose basic volcanics of Paleozoic age that also were mapped as "amphibolite." The great bulk of these schistose Paleozoic volcanics lies to the east of the Mother Lode. That part of the Amador containing the dacitic flows, agglomerates, and tufts, is shown as "diabase," "quartz porphyrite," and "quartz amphibolite." The units shown on the Placerville and Sacramento folios (western part of the section shown in figure 3) as "quartz porphyrite" and "quartz amphibolite" include almost all phases of the Amador, but are chiefly the dacitic volcanics and the quartz porphyry intrusives that represent the volcanic necks from which the dacites were derived.



Fig. 4. Hunter Valley cherts, just east of Jasper Point, Merced River.



Fig. 5. Thin-bedded cherts and tuffaceous slates dipping gently northeastward. Hunter Valley cherts, Amador group, Jasper Point, Merced River.



Fig. 6. Outcrop of massive manganese-stained chert and manganese ore interbedded with thin-bedded cherts. Hunter Valley cherts, 250 feet stratigraphically above pillow basalts. Daly manganese mine, Baxter, Tuolumne County.



Fig. 7. Gently dipping Hunter Valley cherts; looking north across McClure Lake, Merced River, from Jasper Point on the Yosemite Valley Railroad.



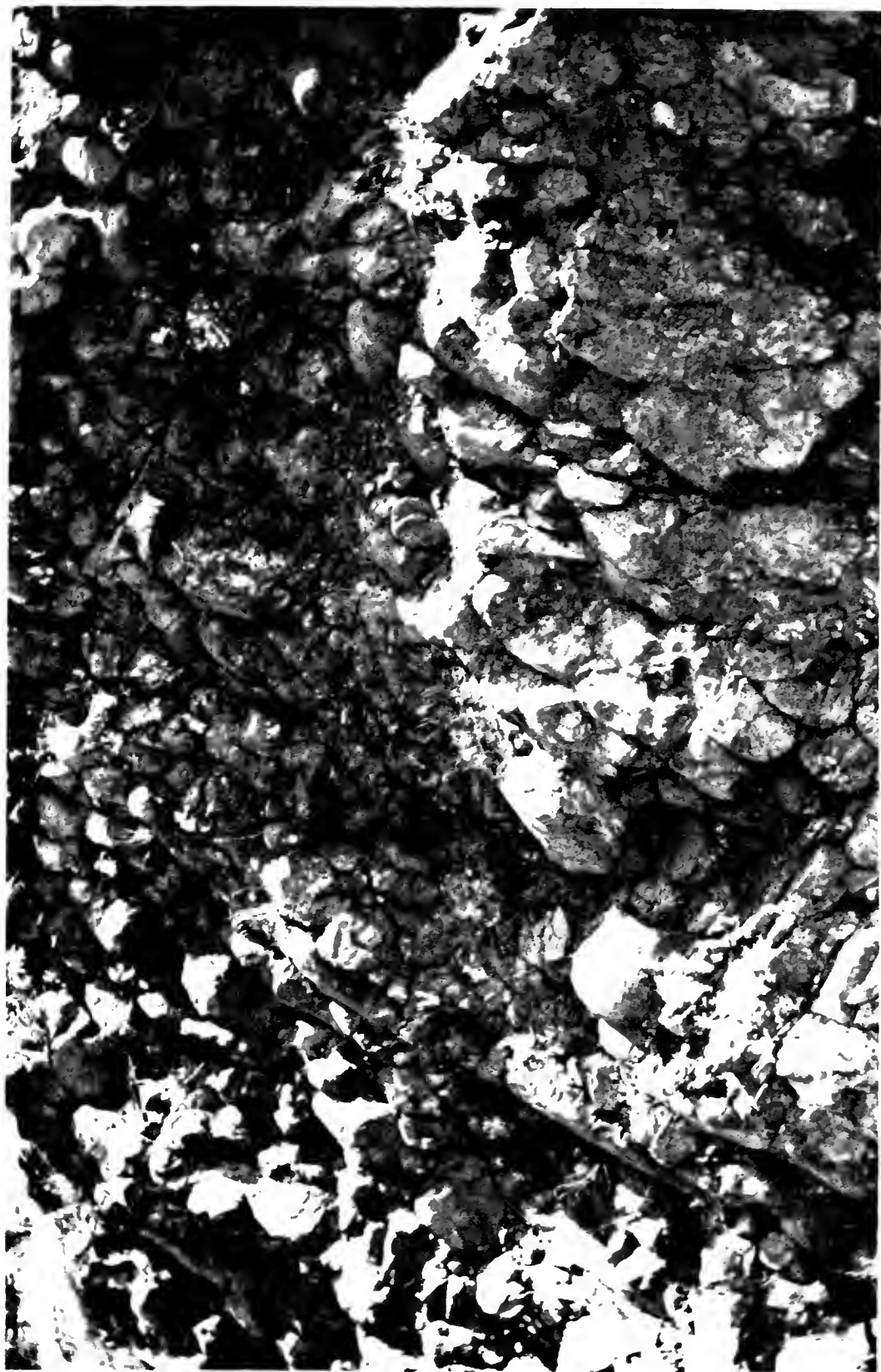


Fig. 8. Pillow basalts below Hunter Valley cherts, Amador group. Cut along Yosemite Valley Railroad, south bank of Merced River.





Fig. 9. Detail of Hunter Valley cherts, quarry at Jasper Point station, Yosemite Valley Railroad, Merced River.



Fig. 10. Detail of the siliceous argillites in the upper part of the Hunter Valley cherts. Hunter Valley, Mariposa County.



Fig. 11. Photomicrograph (x54). Manganiferous slightly tuffaceous red radiolarian chert, Amador group. The dark areas are crypto-crystalline silica stained with black manganese oxide. The Radiolaria are not well preserved but the organic structure of a few is still apparent. Callahan and Donner manganese deposit, Gopher Ridge, western Calaveras County. Bachelor Valley quadrangle, near the western line of the Copperopolis quadrangle.



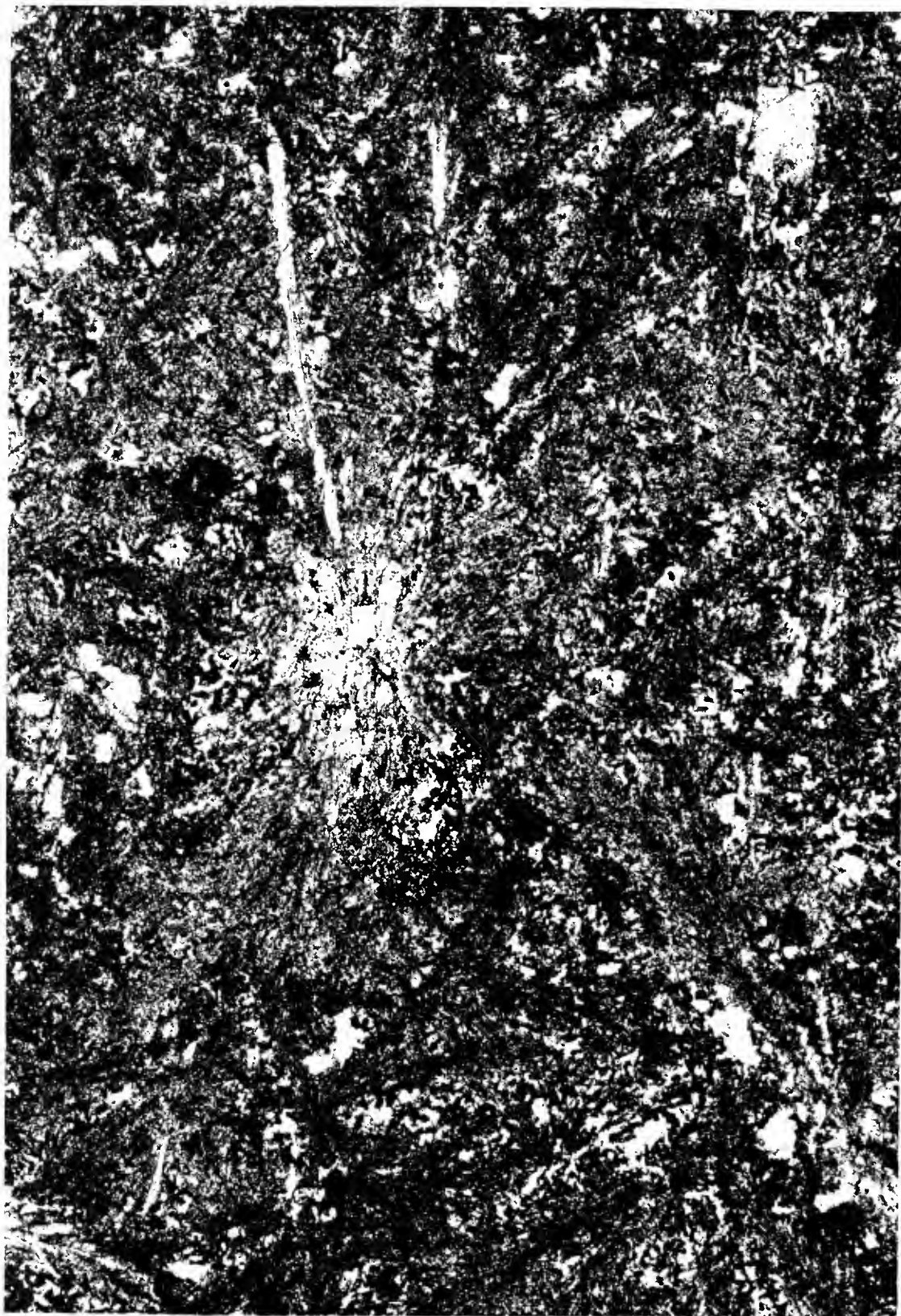


Fig. 12. Photomicrograph (x54). Pillow basalt below Hunter Valley cherts. Amador group, west of Jasper Point, Merced River.

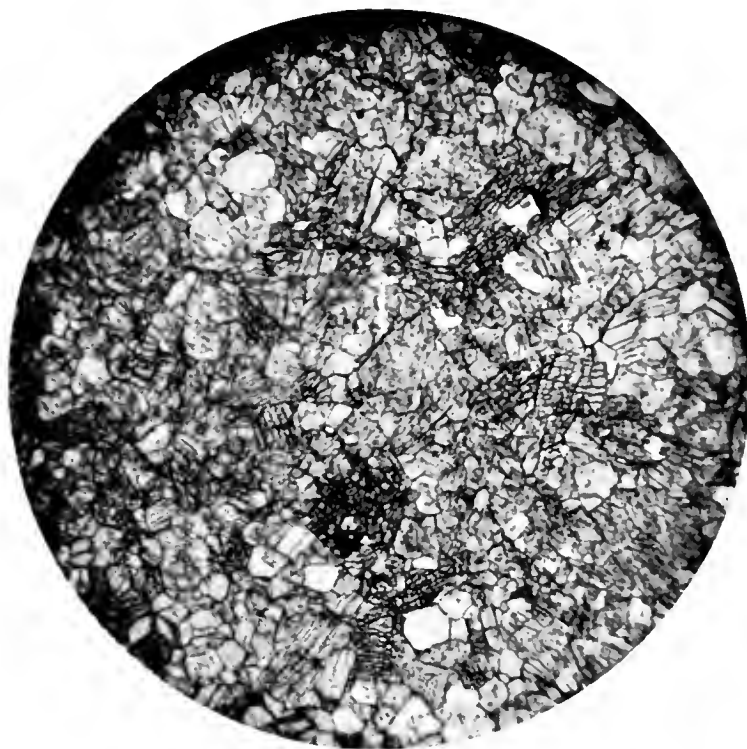


Fig. 13. Photomicrograph (x13). Rhodonite rock, with a little quartz (clear areas) and a few grains of spessartite. From a small roof pendant of Calaveras included in granodiorite, 2 miles west of Tuolumne and 200 yards south of the Sonora-Tuolumne road, Tuolumne County. This appears to represent a completely recrystallized siliceous manganese carbonate.

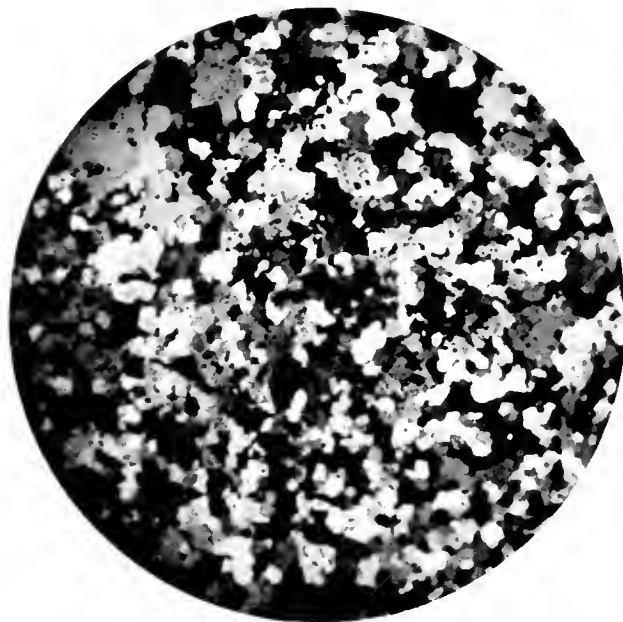


Fig. 14. Photomicrograph (x15), crossed nicols. Completely recrystallized chert near contact with granodiorite. A fine quartz mosaic with very minor amounts of garnet and green hornblende. Squaw Valley, southern Fresno County.



Fig. 15. Photomicrograph (x13). Banded quartz-rhodonite rock. The texture is very similar to that of figure 14. Near contact with granodiorite, Squaw Valley, southern Fresno County.

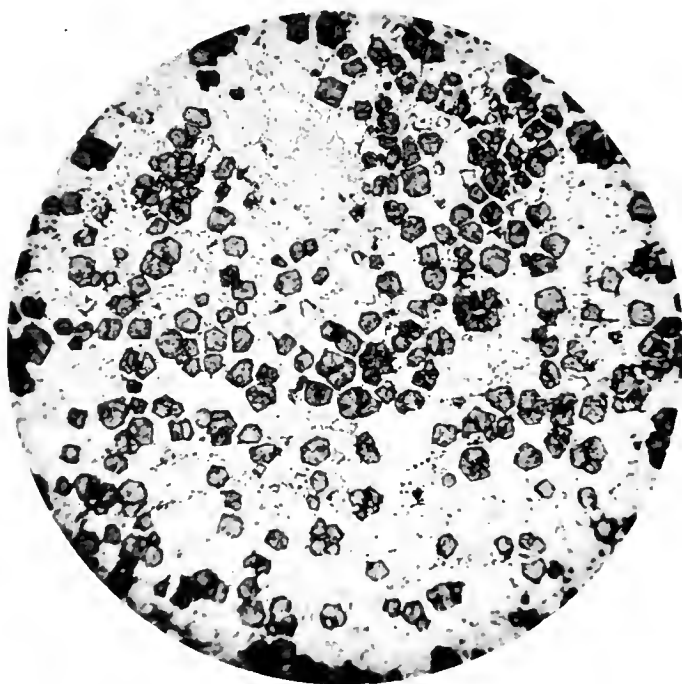


Fig. 16. Photomicrograph (x13). Spessartite-quartz rock. Mosaic of spessartite and quartz. Contact-metamorphosed Calaveras. The garnets have been partially converted to black manganese oxide on the edges and along cracks. Pfortner Ranch, Calaveras County. On ridge south of road from San Andreas to Jesús Maria.

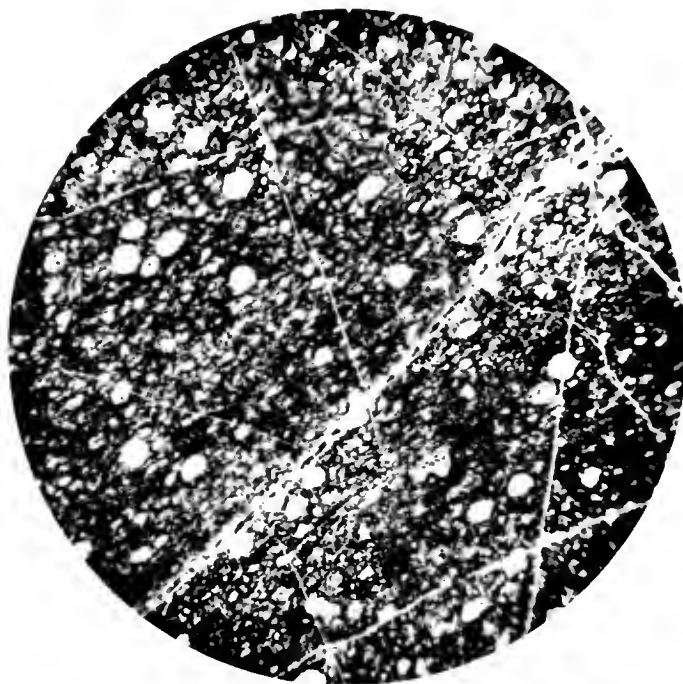


Fig. 17. Photomicrograph (x13). Red radiolarian chert, about 300 feet above the base of the Hunter Valley cherts, 2 miles north of Jasper Point on the Merced River.



Fig. 18. One-fourth natural size. Banded siliceous argillite, near top of Hunter Valley cherts, Merced River.

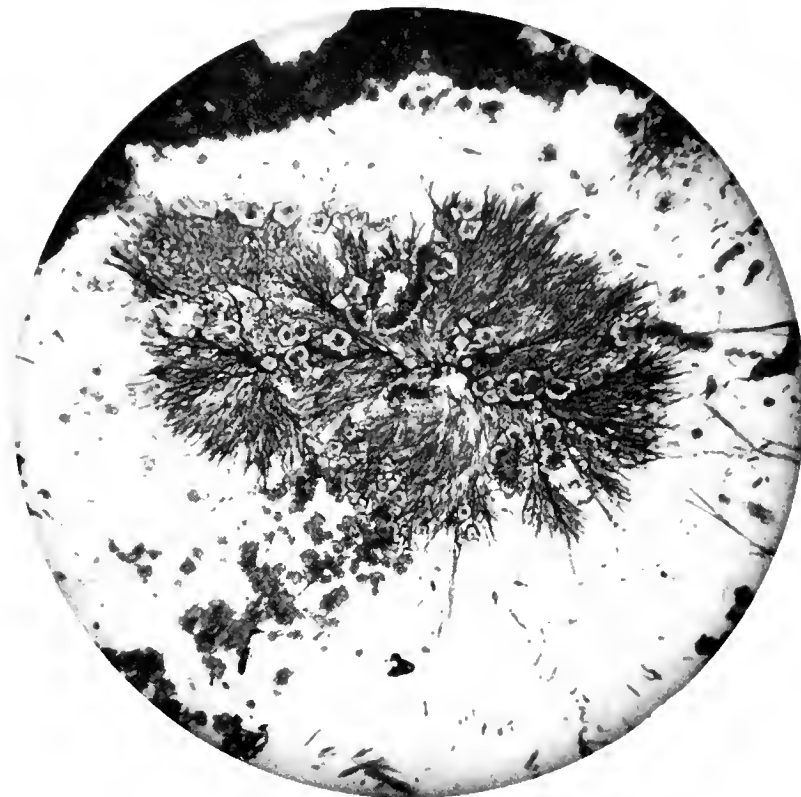


Fig. 19. Photomicrograph (x13). Spessartite surrounded by manganiferous amphibole in a quartz mosaic (diablastic-kelyphitic texture in an ordinary granoblastic texture). Both the garnets and the amphibole alter to black manganese oxide. Metamorphosed Calaveras. Spessartite-quartz lenses in meta-cherts, mica schists, and amphibolites. Carley prospect, Murphy district, Calaveras County.

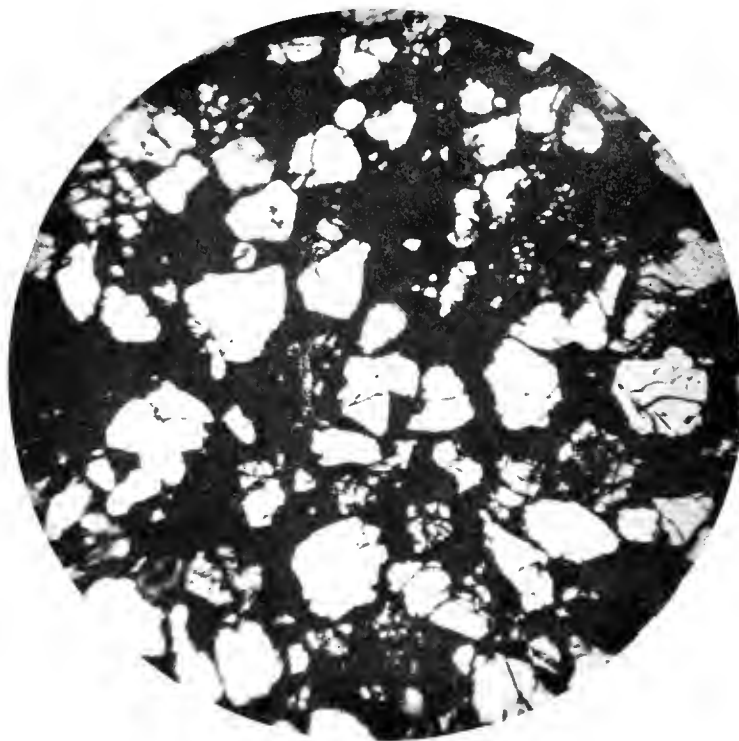


Fig. 20. Photomicrograph (x13). Black manganese oxide cementing a tuffaceous sandstone interbedded with flat-lying Tertiary volcanics,  $1\frac{1}{2}$  miles from Placerville, sec. 16, T. 10 N., R. 10 E., M. D.



Plagioclase, usually albite-oligoclase, occurs sparingly both as small lath-shaped phenocrysts, and intergrown with the feathery augite. Magnetite occurs as minute euhedral grains but is not particularly abundant. Small amygdules, averaging 0.10 mm in diameter, filled with quartz and chlorite (penninite), sometimes are moderately abundant. Chemical analyses have been made and will be given in a future paper.

In field structure, chemical composition, and microscopic texture these appear to be typical albitized pillow basalts or spilites. The almost constant association of radiolarian cherts with such rocks the world over is well known.

The unit which the writer has called the Hunter Valley cherts is made up of red, chocolate, gray, green, and black radiolarian chert, both massive and thin-bedded, with partings of red, lilac, purple, chocolate, gray-green, and black slates and tuffaceous slates. Schistose green tuffs and thin flows also are present. Impure cherts and siliceous mudstones or argillites occur, especially toward the top of the section.

The thin-bedded cherts are rhythmically bedded with vari-colored slates and tuffs. The individual chert layers range from a fraction of an inch to as much as a foot in thickness and average from 2 to 3 inches. The slate and slaty tuff partings usually are thinner but sometimes they predominate over the chert. Massive chert lenses, from 1 to more than 10 feet in thickness, occur in the thin-bedded cherts and also in slates and tuffs or between flows. Usually they occur as pinching and swelling lenses along the same horizon in thin-bedded cherts. The manganese deposits are associated with these more massive cherts. Both the thin-bedded and massive cherts show all the phenomena of pinching and swelling described in the paper on the manganese deposits of the Coast Ranges.

Thin sections of these cherts disclose the presence of numerous radiolarian tests, largely crystallized to a fine quartz mosaic but occasionally showing the remains of organic structure. The cherts usually contain a considerable amount of red iron oxide so finely divided and evenly distributed as to give a uniform red color. The radiolarian remains are free from this pigment and so stand out sharply as minute spots of clear quartz. They are not confined to the red cherts, being present in the green and black varieties also. The radiolarian tests have been too greatly crystallized and flattened for generic determination, but both the suborders *Spumellaria* and *Nassellaria* are represented.

The least metamorphosed cherts consist of cryptocrystalline silica, but with increasing metamorphism the silica crystallizes to a fine quartz mosaic identical with the meta-cherts of the Calaveras. On or near igneous contacts the grain size increases and octahedra of magnetite appear.

In the type section of the Hunter Valley cherts the well-bedded red, green, and black cherts and slates pass upward into massive impure cherts or siliceous mudstones or argillites, apparently homogeneous on fresh fractures but showing on weathered surfaces an exceedingly fine banding.

In the hand specimen these are hard, dense, apparently homogeneous cherty rocks usually green in color, but occasionally banded with red. Under the microscope the rock is seen to consist of cryptocrystalline silica and an amorphous clayey material, the proportion between these two constituents varying widely. With an increase of silica the rocks pass into

dense green and red cherts, while with an increase of the clayey material they become dull, dense, siliceous "mudstones." Under the microscope the clayey material appears as minute clouded isotropic flocci scattered through the cryptocrystalline silica or segregated into bands. This gives rise to the minute banding seen on weathered surfaces. Cryptocrystalline silica occurs even in the most clayey bands, and argillaceous material even in the most siliceous bands. Minute fragments of feldspar, quartz, and altered ferromagnesian minerals are also present and locally become abundant forming tuffaceous layers.

*Partial section of the Hunter Valley cherts, 2 miles north of Jasper Point  
on Merced River*

	<i>Thickness (in feet)</i>
Top concealed by alluvium	
Massive to thin-bedded gray-green slaty siliceous argillites with thin lenses of green chert -----	40
Thin-bedded red radiolarian chert -----	3
Thin-bedded green chert interbedded with slaty green tuffs -----	45
Chocolate-colored slate -----	1
Flow of dense basalt -----	4
Massive red chert -----	1
Dark-brown and chocolate-colored slates with thin lenses of red chert and layers of green tuff -----	7
Coarse dark-green tuff containing fragments of red and green chert -----	2
Thin-bedded red chert -----	3
Olive-green slaty tuff -----	4
Thin-bedded red radiolarian chert with red slate partings -----	22
Gray-green slaty tuffs -----	3
Slaty red argillites -----	3
Fine-grained, pale-red to lilac slaty tuffs -----	4
Thin-bedded green and red cherts with thin slate partings -----	30
Gray-green siliceous slates with thin lenses of green chert and tuff -----	31
Massive red radiolarian chert -----	2
Light-red to lilac slate -----	1
Slaty olive-green tuff -----	3
Tuffaceous slate with thin lenses of siliceous argillite -----	14
Olive-green basic tuff -----	3
Lilac slates and slaty tuffs with small, thin lenses of red chert -----	5
Olive-green basic tuff, slaty -----	15
Lilac and red slates with thin layers of red chert -----	20
Massive red radiolarian chert, stained with manganese. (This is the horizon of the manganese ore in the Daly mine 1500 yards north) -----	9
Dark slate with two thin red chert lenses -----	4
Massive red chert -----	2
Green and red tuffaceous slates with lenses of red and green chert -----	36
Thin-bedded black, gray, and green radiolarian cherts, somewhat crumpled --	10
Thin-bedded gray, green, and black cherts and slate. Chert and slate in about equal proportions -----	22
Gray, green, and red chert with gray and lilac slate partings up to 6 inches in thickness -----	50
Thin-bedded dark-red to chocolate-colored cherts with lilac to purple siliceous slate partings. The cherts average 3 inches and the slates 1 inch in thickness -----	60
Fine-grained olive-green tuff -----	11
Massive black radiolarian chert -----	4
Red and black cherts and slates, somewhat crumpled -----	45
	<hr/> 519
Pillow-basalt at base	

In the typical cherts and slates of the lower part of the formation there has been a very marked separation between the argillaceous material and the silica, which has resulted in sharply separated rhythmically bedded cherts and shales. In the upper part of the formation this clean-cut bedding has not taken place. The writer suggests the following explanation of these facts: In the case of the sharply banded cherts and shales, silica was being added in sufficient quantity and with sufficient rapidity for it to separate out as a chert band, ridding itself of the foreign material in the usual manner. As the amount of silica being added to the waters decreased, or as the amount of argillaceous and fine tuffaceous material increased, a point was reached where the rapidity of accumulation of the two were approximately equal, and a sharp separation did not take place. Moreover, as the proportion of clayey material increased, more and more silica was carried down with it and the necessary concentration of silica delayed. The siliceous mudstones or argillites in the upper part of the formation are frequently tuffaceous and the constant addition of fine ash also might tend to prevent a sufficient concentration of silica for the formation of pure chert lenses.

In the type section of the Hunter Valley cherts the lower bedded radiolarian cherts and slates grade upward into massive siliceous mudstones. Although it is not certain whether this indicates a decrease in the amount of silica added to the water, or an increase in fine clayey and tuffaceous material, it is believed to indicate a decrease in silica. Radiolaria are rarely present in the siliceous mudstones.

The following is a detailed partial section of the Hunter Valley cherts, measured about 2 miles north of the Merced River and about a quarter of a mile south of the Daly manganese mine.

#### Manganese Deposits of the Amador

The more massive cherts of the Amador group are not infrequently stained with manganese, but local concentrations of economic importance are not common. Oxidation rarely has extended to more than a few feet beneath the surface and the unoxidized ores are too high in silica to be of value. Eleven deposits are known in the Amador group in Amador, Calaveras, El Dorado, Fresno, Mariposa, and Tuolumne Counties. Ore has been shipped from but 5 of these deposits and the maximum production of even the best has been less than 300 tons.

The ore always occurs in distinct bedded lenses which lie parallel to the enclosing cherts and shales, or as small bands or lenses within the more massive cherts. These lenses seldom occur singly but as a train of lenses along a definite stratigraphic horizon. Moreover, the individual lenses frequently pinch and swell, a phenomenon which may also be observed in many of the chert lenses. In fact there is little difference in mode of occurrence between lenses of chert and lenses of ore, and in several cases, notably in the Daly mine in Mariposa County, and the Hughes mine in Tuolumne County, lenses of massive brick-red chert and lenses of ore occur along the same stratigraphic horizon. Usually the ore occurs along only one horizon but in a few instances small lenses separated by a few feet of chert and shale have been found. Most of the phenomena shown by the Franciscan deposits are shown by those in the Amador.

### Character of the Ore

The only ores of economic importance are the black oxides, of which there appear to be several varieties, that are developed at or near the surface from the primary minerals. The earliest product of oxidation is an impure dull to glossy black oxide, usually high in silica. Subsequent migration and concentration of the manganese results in the formation of pyrolusite, psilomelane, cryptomelane, etc. Even the best of the black oxidized ores rarely exceed 45 percent manganese or contain less than 10 percent silica.

### Primary Minerals

The primary minerals from which the black oxides are derived are of two types, namely, the original syngenetic substances deposited contemporaneously with the cherts, and those substances developed by metamorphism.

Just as is the case with the Franciscan deposits, manganiferous opal (neotocite) and manganese carbonate, usually containing a considerable amount of lime, are the original chemical deposits from which all the other manganese minerals have been derived. Manganese carbonate, or manganese-calcium carbonate, is much less common than in the Franciscan, the manganiferous opal having been the chief original substance. However, small amounts of manganese carbonate are nearly always present. The original manganiferous opal has been largely altered to fibrous and granular aggregates of hydrous manganese silicates of the bementite type, similar to those in the Franciscan deposits. These vary from bright yellow to deep red-brown in color; they also vary in refractive index and birefringence. In a few of the least altered deposits the neotocite-bementite-carbonate mixtures have been only partially altered to rhodonite and constitute a considerable proportion of the material from which the black oxide ores are derived. These alter to a glossy black oxide with cores of powdery silica. However, in most cases the alteration to rhodonite and other minerals has been considerable or even complete.

Manganese carbonate is relatively rare and does not form independent orebodies of any appreciable size in the Amador. It usually occurs as small lenses or irregular areas in the siliceous ores or as spherulitic aggregates or small lenses in the cherts. It is fine-grained and often impure and cloudy, owing to the presence of fine tuffaceous or clayey substances. In color it varies from gray to pale pink, depending on its purity. Qualitative chemical tests usually show that calcium is present and it appears to have been deposited originally as a manganese-calcium carbonate.

No well-crystallized veins of rhodochrosite have been found in the Amador deposits. In the Franciscan deposits veins of well-crystallized rose-pink or flesh-red rhodochrosite are common. On the other hand, rhodonite as fine-grained aggregates and as veins is common in the Sierra Nevada, while rhodonite is very rare in the Coast Ranges, the silicates being the relatively low-temperature minerals, such as inesite, the hydrous silicate of manganese and calcium.

The minerals that have been developed by metamorphism and hydrothermal alteration are rhodonite, recrystallized manganese-calcium car-

bonate, spessartite, manganocalcite, manganosiderite, and piedmontite, the manganiferous epidote.

The rhodonite, developed from the manganiferous opal-bementite-carbonate aggregates, usually is very fine-grained and forms dense, tough rocks, gray, greenish gray, pink, or rose red in color. They are finer grained than most of the Calaveras rhodonite rocks. Pure rhodonite or rhodonite-quartz rocks are not common as the conversion of the original aggregates to the anhydrous silicate rarely has been complete. The rhodonite develops in irregular areas, giving rise to dense, mottled rose-red, brown, gray, and gray-green rocks. Much of the so-called rhodonite appears to be the manganese-calcium silicate, bustamite. However, in the absence of chemical analyses, the manganese silicate that oxidizes into the black oxide ores will be called rhodonite.

Veins of secondary rhodonite or of rhodonite and quartz are common. The rhodonite occurs as bladed crystals transverse to the walls or, less commonly, as granular aggregates. Usually the veins are very narrow but some attain a width of 3 or 4 cm.

Manganese garnets are very rare in the Amador deposits and occur only in those that have been affected by contact metamorphism. They have been recognized only under the microscope as small grains and crystals in rhodonite-quartz rocks.

Manganocalcite and manganosiderite appear to have been secondarily formed by carbonated surface waters that have taken up a small amount of manganese in their downward passage. These minerals occur in small veins and irregular areas and appear to be analogous to the calcite veins that cut the cherts and associated rocks.

The Amador volcanics frequently have been strongly epidotized, sometimes over large areas. In the deposits, or even in the manganese-stained cherts, the manganiferous epidote, piedmontite, is common. It occurs as veins and as small grains or aggregates of grains in the ore, either oxidized or unoxidized, and in the manganiferous cherts associated with the ore. It is readily identified by its strong and characteristic pleochroism.

#### Descriptions of Some of the More Important Deposits

Before considering the nature of the original substances and the manner of their deposition a few of the more important deposits will be described.

*Daly Mine, Mariposa County.* This is 8 miles southwest of Coulterville and 2 miles north of Merced River. It is a few hundred yards north of the detailed section of the Hunter Valley cherts given previously.

Lenses of oxide ore interbedded with red cherts occur about 250 feet stratigraphically above the top of the pillow basalt which underlies the cherts and tufts. In the section given, the ore horizon is represented by a massive lens of red chert 9 feet thick. To the north of the section, pinching and swelling lenses of red chert occur along this horizon for a distance of about 300 yards. These cherts are frequently stained with black manganese oxide which increases in amount northward. The most northerly exposure of this red chert contains a considerable amount of impure black manganese oxide as a shell or crust on the surface or as films along cracks. A lens of black manganese oxide appears 300 feet to

the north and along the same horizon. At least four lenses occur along this horizon for a distance of 600 feet. Several small pits and shafts, the deepest being only 18 feet, have been sunk on these lenses. Along the surface and in these shallow workings lenses of black oxide ore up to 2 feet in width are exposed. One of these lenses has been bottomed at a depth of about 10 feet, showing that they pinch out in all directions. These lenses everywhere conform to the bedding of the cherts and slates in which they are inclosed.

Here and there within the ore, cores of unoxidized rhodonite and manganese carbonate occur. These are so exceedingly dense that the individual grains can only rarely be made out with the hand lens. Under the microscope these dense rocks are often seen to be finely banded, lenses or layers of carbonate alternating with rhodonite. Sometimes they are composed almost wholly of dense, fine-grained rhodonite with lenses of manganese carbonate. Cryptocrystalline silica is nearly always present.

Small chert lenses occur within the ore and these usually contain fine layers of carbonate and rhodonite; similar small layers also occur within the cherts of the hanging wall. Grains of piedmontite also occur in these carbonate-rhodonite-quartz mixtures.

The following is a partial analysis of the unoxidized material:

	<i>Percent</i>
SiO <sub>2</sub> -----	35.97
Al <sub>2</sub> O <sub>3</sub> -----	4.42
Fe <sub>2</sub> O <sub>3</sub> -----	5.96
MnO -----	27.10 = 21.0 percent Mn.
	<hr/> 73.45

Qualitative tests show the presence of considerable calcium and carbon dioxide and the manganese carbonate is probably impure, containing calcium and iron in addition to the manganese.

The oxidized ore, in part true psilomelane, and in part a dull black impure manganese oxide, is derived from this rather low-grade primary material by direct oxidation. The oxide ore as a whole averages about 40 to 45 percent manganese and 10 to 15 percent silica. About 250 tons of ore of this grade has been shipped.

*Hughes Mine, Tuolumne County.* A small deposit occurs about 6½ miles northwest of the Daly mine and at about the same or at a slightly lower horizon in the cherts. The mode of occurrence is the same at both localities except that only one lens of ore has been found at the Hughes mine. The primary ore consists of finely granular rhodonite similar to that at the Daly mine except that it contains residual patches of hydrous manganese silicates.

*Gorham Prospect, Calaveras County.* An undeveloped prospect was found on Loucks Creek, about 5 miles southeast of Copperopolis. Several lenses of ore, interbedded with red radiolarian cherts and slates, occur over a distance of 600 feet. Four to six feet above this ore horizon and separated from it by barren red cherts and slates is a second zone of lenses of more limited extent. None of these is large, the largest being 20 inches thick and 30 feet in length. Oxidation has taken place at most to a depth of only a few inches, and primary ore is frequently exposed at the surface,

The unoxidized primary ore consists entirely of a brown resinous neotocite-bementite mixture containing patches and irregular areas of secondarily developed, exceedingly fine-grained pink to red rhodonite. No manganese carbonate was seen in the hand specimens but in one thin section a few small lenses were found. To the south the ore horizon is represented by red radiolarian cherts containing lenses and irregular areas of rhodonite.

Under the microscope the manganiferous opal is a clear yellow-brown color and almost completely isotropic. Here and there small patches of fibrous manganese silicates and irregular areas of very fine-grained rhodonite occur. Several identical economically unimportant deposits occur in the Bear Mountains 10 to 12 miles to the northwest.

*Gopher Ridge Deposits.* Two deposits occur in thin Amador cherts and slates interbedded with volcanics along Gopher Ridge, east and south-east of Milton. Here they have been intimately intruded by thick sills and irregular bodies of quartz porphyry which have incorporated blocks of the volcanics and the red and green cherts and siliceous argillites. They are of no economic importance as little oxide ore has been developed. The deposits consist chiefly of dense rhodonite and manganese-calcium carbonate. Radiolarian remains were found in the carbonate.

*Amador County Deposits.* A belt of red cherts, siliceous green mudstones, and tuffs interbedded with basic volcanics and intruded by diabase and serpentine extends northward from Mokelumne River at least as far as the latitude of Ione; this is a continuation of the Bear Mountain belt to the south.

The red cherts are here and there lightly stained with black manganese oxide and one small low-grade deposit occurs about  $3\frac{1}{2}$  miles east of Ione. Three shallow cuts have been made along the manganiferous red cherts but no commercial ore has been encountered. The manganese ore occurs as small lenses in a massive red chert 6 to 12 feet thick. When unoxidized these lenses consist of fine-grained pink rhodonite rock with small residual patches of resinous brown hydrous manganese silicates. Under the microscope the silicates appear in very irregular clear yellow patches, which, with crossed nicols, are seen to be made up of yellow fibers. No carbonate is present.

Lenses of hematite occur in both the massive red chert and in the thin-bedded cherts. Frequently the thin-bedded cherts have partings of siliceous hematite in which small octahedra of magnetite have been developed. These small lenses of iron ore are similar to the manganese lenses in mode of occurrence and undoubtedly represent sedimentary iron deposits. Similar hematite and magnetite beds or lenses occur in the cherts in Fresno, El Dorado, and Butte Counties.

*Crisle Prospect, Fresno County.* A metamorphosed deposit occurring in red and gray recrystallized cherts intercalated in volcanic rocks occurs in southern Fresno County, 9 miles northeast of Piedra.

The cherts in which this deposit occurs very probably belong to the Amador group as they are of similar lithologic character and stratigraphic position to the cherts found to the north. These have been thermally metamorphosed by large batholithic masses of granodiorite. The cherts have been recrystallized but they are exceedingly fine-grained and



still preserve their dense cherty appearance in places. They are far less metamorphosed than the Calaveras cherts that occur to the east and southeast.

These cherts are red to gray in color and are both massive and thin-bedded, the latter having thin partings of quartz-sericite schist.

Lenses of dense rhodonite rock and quartz-rhodonite rock occur in layers interbedded with the thin-bedded cherts and as small, somewhat contorted lenses in the more massive cherts. These layers are banded within themselves and show alternate bands of almost pure rhodonite rock alternating with quartz-rhodonite rock and chert. All of these lenses are small and little oxide ore has been formed.

#### Thermal Metamorphism of the Deposits

In Fresno and El Dorado Counties the deposits of the Amador group occur in close proximity to large granitic stocks or batholiths. Although no deposits have been found at the direct contact, nor have the cherts been traced to their actual junction with the igneous rocks, the effects, even at considerable distances, have been marked. The red iron-rich cherts have been converted into dense, vitreous, often greenish rocks containing numerous small octahedra of magnetite. Under the microscope these are seen to consist of brown biotite and green hornblende in minute flakes and grains scattered through a very fine-grained quartz mosaic. Small garnets occur sparingly, while grains of magnetite are abundant. The less iron-rich cherts are exactly similar except that they are red, white, or gray in color and contain little or no magnetite, the iron having gone into biotite, hornblende, and garnet; these are identical with many of the meta-cherts of the Calaveras. The hematite deposits which occasionally occur have been converted into magnetite. The manganese deposits have been converted into rhodonite and quartz-rhodonite rocks similar to those already described under the Calaveras deposits, except that those in the metamorphosed Amador rocks are finer in grain. Garnets rarely occur and then only as minute grains or crystals in the quartz-rhodonite rocks. The same notable banding observed in the Calaveras deposits may be seen in the metamorphosed Amador deposits. Layers or lenses of rhodonite rock occur in quartz-rhodonite rock and in the crystallized cherts.

Residual patches of manganese carbonate and hydrous manganese silicates sometimes occur in the rhodonite rocks.

#### Banded Character of the Deposits

One of the most striking features of many of the deposits is the remarkable banding which they exhibit, not only in the hand specimen but also in thin section.

This banding may be divided into two types: one in which the primary constituents are themselves banded, the other in which they are banded with chert. In neither of these types do the bands extend for any great distance; rather they are more in the nature of lenses or trains of lenses, one band dying out and being replaced by another. Frequently the carbonate occurs as lenses in the neotocite, sometimes as a series of small pinching and swelling lenses which form a more or less continuous band for several inches. Frequently the neotocite has been converted into



fine-grained rhodonite without the destruction of the banding, and lenses of recrystallized carbonate, often somewhat bent or contorted, occur in exceedingly fine-grained rhodonite rock. Bands and lenses of chert also occur in the ore.

Thin bands and lenses of carbonate and of brown siliceous ore often occur in the midst of a bed of radiolarian chert, sometimes singly but more frequently in trains of lenses. Only in one instance have radiolarian remains been found in these small layers of ore within the chert. However, in the less metamorphosed deposits of the Coast Ranges well preserved radiolarian remains have been found in the ore in several instances.

The orebodies are always bedded with the cherts and the fine banding found within these bodies is always parallel to the bedding planes.

#### Similarity Between the Amador and Calaveras Deposits

The deposits in both of these groups occur as bedded lenses in cherts. Not only are the orebodies everywhere parallel to the bedding of the cherts but they show internal banding of the various constituents and this banding is always parallel to the bedding. Although the Calaveras deposits have been severely metamorphosed and rendered crystalline, the original bedding and the fine banding have not been destroyed but are preserved in the alternating layers of the rhodonite-spessartite-quartz series.

Although one is much older than the other and their histories subsequent to their formation have been somewhat different, there is no fundamental difference in their mode of occurrence and origin.

#### Tertiary Manganese

Only one manganese deposit of Tertiary age is known to the writer in the Sierra Nevada. This occurs in El Dorado County, about  $1\frac{1}{2}$  miles southeast of Placerville; no development work had been done and the deposit is poorly exposed, being largely covered with soil and hill wash.

Along the south slope of a lava-capped ridge, outcrops of a tuffaceous sandstone cemented by black manganese oxide may be traced for a distance of about 150 feet. This sandstone occurs in flat-lying Tertiary volcanics and is interbedded with rhyolite tuff below and andesitic agglomerate above.

The black oxide matrix makes up an appreciable part of the rock, assays of this material giving as high as 25.9 percent metallic manganese. Under the microscope the rock is seen to consist of rounded to sub-angular grains of quartz, orthoclase, a little oligoclase, and a few flakes of mica in a matrix of black manganese oxide.

The original form of the manganese is not known. It may have been deposited as carbonate or as oxide. The volcanics with which it is associated are known to have been poured out on land, and since it is quite probable that the sandstone was deposited in contact with air or in oxygenated stream waters, it seems more reasonable to suppose that the manganese was originally deposited as oxide.

The origin of the manganese is purely a matter of speculation, but since it is so closely associated with volcanic rocks it may have been

derived from the leaching of tuffs or flows containing small amounts of manganese, or it may have come from a local manganiferous spring having its source in the volcanics.

That the manganese was not introduced after the deposition of the sandstone is indicated by the fact that the mineral grains isolated in the black oxide matrix show no sign of replacement.

A few small crusts and concretions of an impure black manganese oxide were found in a pebbly, somewhat clayey, rhyolite tuff three-eighths of a mile south of Placerville. Small quartz pebbles present also are sometimes lightly stained with manganese.

#### Origin of the Deposits

The manganese deposits of the Sierra Nevada are always bedded with cherts and behave in all respects as normal members of a sedimentary series. The various primary constituents are usually banded and this banding is everywhere parallel to the bedding. In mode of occurrence there is no essential difference between the lenses of ore and the more massive lenses of red radiolarian chert. Both occur as pinching and swelling lenses or as trains of lenses along a definite horizon. Moreover, small lenses occur within beds of radiolarian chert, the ore sometimes containing radiolarian remains.

Taking all of these facts into consideration there seems to be no escape from the conclusion that the manganese deposits are chemical sediments syngenetic with the inclosing cherts. No other hypothesis will explain the bedded character and minute banding so universally present.

Furthermore, the stage of metamorphism of the bedded lenses and of the inclosing cherts agree. In the more severely metamorphosed deposits the cherts consist of a crystalline mosaic of quartz in which occur such secondary silicates as hornblende, biotite, and garnets, while the original manganiferous substances have been converted into the denser silicates such as rhodonite and spessartite.

In origin the Sierra Nevada and Coast Range deposits are similar. No mode of origin has previously been suggested for the Sierra deposits but Harder<sup>30</sup> after a brief study of the Coast Range deposits concluded that they were secondary concentrations along zones of faulting, the jaspers being the source of the manganese. However, at the time of Harder's visit none of the mines had been worked below the zone of oxidation and only the oxide ore was exposed. In such oxide bodies secondary concentration and migration of the manganese oxide often obscures the true relations. The oxide frequently migrates into cracks in the cherts in the vicinity of the deposits giving an appearance of replacement. However, replacement of the chert by the primary constituents has never taken place.

#### Form in Which the Manganese Was Originally Deposited

This subject has been discussed in the paper on the manganese deposits of the Franciscan<sup>31</sup> and since it is believed that the manganese

<sup>30</sup> Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, pp. 166-167, 1910.

<sup>31</sup> Taliaferro, N. L., and Hudson, F. S., Manganese deposits of the Coast Ranges, this bulletin.

deposits of the Coast Ranges and the Sierra Nevada had a similar origin a detailed discussion is not necessary.

It is sufficient to state that it is believed that the manganese was originally deposited as a chemical sediment, either as a manganiferous silica gel or, if sufficient carbon dioxide was present, as the carbonate. The chief evidence for this belief is the presence of these substances in the least metamorphosed deposits as bedded lenses inclosed in thin-bedded cherts and slates or as lenses within more massive cherts. Moreover these original substances sometimes contain radiolarian remains just as do the cherts with which they are associated.

#### Source of the Manganese and Silica

Because of the very close and constant association of the manganese deposits with cherts, not only in the Sierra Nevada but also in the Coast Ranges of California, and in many other parts of the world, it is believed the manganese, in deposits of this type, was derived from essentially the same source as the silica forming the cherts. In this connection it is significant that practically all of the manganese deposits are associated directly with the thicker and more massive chert lenses interbedded with the thin-bedded cherts. It is believed that these more massive chert lenses represent a more rapid local addition of silica to the sea water. As pointed out in the discussion of the Franciscan deposits this is the only evidence that favors the theory that the source of both the manganese and the silica was from submarine springs derived from the volcanics rather than from the leaching of volcanics.

As the subject has been discussed several times previously it is only necessary to state that it is believed that both the silica forming the cherts and the manganese had their origin in the volcanic rocks with which they are associated.

#### SUMMARIZED HISTORY OF THE DEPOSITS

The history of the manganese deposits of the Sierra Nevada may be briefly summarized as follows:

*First*, the manganese was introduced and deposited with the silica in colloidal form as a manganiferous silica gel, or in the presence of carbon dioxide, as manganese carbonate. Both the silica forming the cherts and the manganese were derived from the associated volcanics, either from siliceous, manganiferous, and ferruginous springs or emanation, or by leaching.

*Second*, the syngenetic deposits and the associated cherts and volcanics were buried under subsequent volcanics and sediment.

*Third*, near the close of the Jurassic, the Calaveras, Amador, and the Mariposa were closely folded and commonly overturned and, in many places, intruded by batholiths of granodiorite. The resulting metamorphism converted the original substances either wholly or partially, depending on severity and the proximity to intrusive igneous rocks, into rhodonite, or in the case of the older Calaveras sediments, into rocks of the rhodonite-spessartite-quartz series.

*Fourth*, in the ensuing uplift and erosion many of the deposits were completely removed. Those that remained at the surface as late as the middle Eocene probably were deeply oxidized.

*Fifth*, the late Tertiary and Pleistocene uplift of the Sierras and the consequent erosion removed any deeply oxidized ores formed in the early Tertiary and exposed the unoxidized parts of old deposits or, more probably, entirely new deposits.

*Sixth*, in the comparatively brief time since the latest uplift, oxygenated surface waters have converted the primary minerals (original substances and those developed by metamorphism) into black oxide ores. However, the time since the latest uplift has been so brief and erosion so active that oxidation has not extended to any great depth and high-grade oxide ores are of relatively uncommon occurrence.

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## O





### Economic Aspect

### History of Production

Manganese mining in California started in 1887 at the Lath mine in San Joaquin County. Between 1887 and 1914, California ranked first high in manganese production compared with the rest of the country, most of the ore coming from the Lath mine. Production declined after 1900 and mining all but ceased until the urgent demand created by World War I stimulated domestic production. Some 60,000 tons was produced between 1914 and 1920, the largest annual output being 1917. In 1919, many mines were closed just getting into production when the war ended. This was followed by a sudden drop in the market, and as a result a number of California producers were compensated by the Federal government for losses incurred during the war. Only a small, sporadic production was recorded in the post-war period, the total between 1921 and 1940 being 18,000 tons. The amount brought about by World War II was again revived, but this time the California ore is now bought and stockpiled by the Federal Metals Reserve Company under considerably higher prices and lower specifications than those prevailing in peacetime.

### Uses

Manganese is most prominently in steel manufacturing. Some 10 pounds are being pumped into the pot of molten iron, then the steel. The manganese removes oxygen and sulphur, and helps in controlling the carbon content, and a small part passes into the steel, imparting certain desirable properties. Manganese is mostly added in the form of ferro-manganese, an alloy of manganese and iron containing about 80 percent of manganese. For this purpose an oxide ore is desired that is free of lead, boron, phosphorus, and nickel. The ore contains 7 percent of iron, 16 percent of alumina, 10 percent of silica, 1 percent of zinc, and 0.18 percent of phosphorus. Silica, manganese, an alloy of manganese and carbon, is sometimes used in steel manufacture, but is less chosen because the silica is more expensive than that in ferro-manganese. Sprag is used in the form of a steel strip containing about 10 percent manganese and 0.05 percent of carbon, and is used in the form of a steel rod.

Manganese is also employed in making permanent alloys. Steel containing about 1.2 percent manganese has high tensile strength and is much used for frags of crissing. When alloyed with chrome and nickel-steels, with aluminum with copper, and with various bronzes, manganese increases resistance to corrosion.

Manganese oxide is used in making dry cell batteries. For this purpose the ore should be high in available oxygen and low in metals that react electrically with zinc, such as iron, copper, nickel, cobalt, and arsenic. Many of the Por Range hematite ores have proved suitable for this purpose.

Other uses for manganese are found in the glass, ceramic, paint, and chemical industries, and it is also used as fertilizer.

\* Abstract drawn from the paper presented at Balkan 1975, devoted to the collaborative study of Mammals and prepared in cooperation with the United States Department of the Interior Geological Survey.

STATE OF  
DEPARTMENT OF N  
DIVISION

WALTER W BRADLEY

## OUTLINE (if

# CALIF

SHOWING L

# MANGANESE

PREPARED UNDER  
OLAF P. JENKINS

GEOLOG

IN COUPE

UNITED STATES DEPARTMENT OF

Scale

(Approximately)

ECONOMIC MINERAL  
No. 5-M

19

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# STATE OF CALIFORNIA DEPARTMENT OF NATURAL RESOURCES DIVISION OF MINES

W. BRADLEY, STATE MINERALOGIST

## LINE GEOLOGIC MAP OF CALIFORNIA SHOWING LOCATIONS OF MANGANESE PROPERTIES

DRAWN UNDER THE DIRECTION OF  
P. JENKINS, CHIEF GEOLOGIST  
GEOLOGIC BRANCH

IN COOPERATION WITH  
DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY

Scale 1:100,000  
Approximately 1 inch = 16 miles

### C MINERAL MAP OF CALIFORNIA NO. 5—MANGANESE

1943

APPROXIMATE TONNAGE MANGANESE ORE PRODUCED  
(INCLUDING YEAR 1942)

Class  
A 1,000 TONS AND OVER

#### Unit of Manganese

The price of manganese ore is ordinarily based upon a "unit" of manganese, which is 1 percent of a long-ton dry, or equivalent to 22.4 pounds of metallic manganese.

#### Government Specifications and Prices

The Federal Metals Reserve Company (subsidiary of Reconstruction Finance Corporation) issues specifications and prices under which they will purchase manganese ores. These range (May 15, 1943) from a basic content of 48 percent Mn, and \$1.00 per long-ton unit, down to a minimum acceptable of 35 percent Mn, with premiums for higher Mn percentages and lower impurities than the base points, and with penalties for Mn between 48 percent and 35 percent and higher impurities.

As these specifications and prices have been and may again be changed at intervals as the war necessities require, anyone interested should consult either the Metals Reserve Company or the State Division of Mines for the latest data. These specifications refer to black oxide ores, manganese carbonate ores are accepted only if reduced. Manganese concentrates are acceptable only if nodular or sintered. The size of ore must not be over 12 inches, and not more than 25 percent should pass a 20-mesh screen.

#### Purchase Deposits

Deposits for purchase of small lots of manganese ore and other strategic minerals (not less than 10 tons to each lot) have been established by the Metals Reserve Company at Anderson, Arizona, Ashland, Fresno, Oroville, Quincy, Tracy, and Yreka, and also Grants Pass, Oregon, and Parker, Arizona. Deposits for purchase of carbon lots under contract are located at Sacramento and at Phoenix, Arizona. Other possible buyers of manganese ore in California are the General Dry Battery Company at Patterson, and the Kaiser Company, Inc. Iron and Steel Division, Fontana.

#### Tenor of the Ore

The maximum theoretical percentage of manganese in pure manganese minerals is 72.1 percent in hausmannite and 13.2 percent in pyrolusite. The best ore mined in California contains about 36 percent manganese, however, and very few ores contain more than 50 percent. The great majority of California ores shipped fall below the limit of 48 percent which is the general minimum desired in peacetime, and most of them come closer to the present limits set by the Metals Reserve Company of 35 to 40 percent manganese. A much larger quantity of lower grade ore is present in the state, containing less than 35 percent manganese.

Of the undesirable impurities listed in the Metals Reserve specifications for "High Grade" ore, alumina, phosphorus, and zinc in California ores are generally well below the maximum allowed. Also, most of the California ores shipped contain only 1 or 2 percent of iron, although iron-rich ores occur in the state. Silica is the most troublesome undesirable constituent in ores of the Coast Ranges and Sierra Nevada, the mined in these regions commonly contains more than 10 percent and sometimes as much as 30 percent of silica. This is expected, inasmuch as these areas were deposited in shaly rocks (chert), and a greater or lesser amount of the silica with the manganese is inevitable, in fact silica has been chemically combined with the manganese in bementite, rhodonite, spessartite, and braunite ores. On the other hand, the fissure deposits in the Mojave Desert region are usually low in silica.

#### Treatment of the Ore

Hand sorting is generally the only treatment given to California manganese ores. Most of the oxide ores are not particularly amenable to mechanical concentration. Electro-magnetic and electrostatic methods are said to have been applied with some success. The manganese in low-grade oxide ores, and also that in rhodochrosite, braunite, and bementite, is soluble in  $H_2SO_4$ , and leaching with these substances may prove feasible in case enough ore can be found to warrant the construction of a leaching plant.

#### Prospecting

The chief aid in recognizing manganese minerals are that they are usually heavier than ordinary rocks, and that all of them are black when weathered. Many of the manganese oxides are soft and soapy and leave black smudges on the hands when touched, some of them, however, are hard and flintlike.

Nearly all of the manganese deposits in the Coast Ranges and Sierra Nevada are enclosed in chert, or its metamorphic equivalent which resembles quartzite. Manganese deposits should therefore be searched for in areas of these rocks. The deposits in the Mojave Desert region occur in fissures in various types of rock, mainly volcanic rocks and fanglomerate, and these deposits are best found by tracing that of manganese oxide.

Iron oxide is sometimes combined with manganese oxide, but may be distinguished by the different streak or color of the powder of the mineral, which may be determined by scratching with a knife. The streak of hematite is black-red or reddish-brown, that of limonite is yellowish-brown, whereas the manganese oxides possess a black or dark brownish-black streak.

Many rocks which are merely stained or coated with thin films of manganese oxide are mistaken for solid ore. They may be distinguished by their lighter weight or by breaking them until a fresh surface is exposed.

#### Geologic Aspect

Manganese never occurs as an element in nature, but is always chemically combined in mineral compounds. Over 100 minerals are known to contain manganese, only a few, however, occur in large quantities in nature.

The "black oxide" minerals, which include pyrolusite, manganite, "wad", and minerals of the "psilomelane type", are difficult to distinguish with certainty except by X-ray methods. However, the black oxide minerals mined in California have been most commonly referred to as "pyrolusite" and "psilomelane". Pyrolusite is soft, black, sooty, often crystalline, it may usually be crumbled with the fingers. Minerals of the "psilomelane type" are usually harder than the black oxide, black or bluish-black, massive, often botryoidal or nodular in outline, and they often possess a conchoidal fracture.

Hausmannite, which contains the highest percentage of manganese of any of the manganese minerals, is a dark reddish-brown mineral having a brownish streak. It has been mined in the Mad River region in Trinity County, and in San Luis Obispo County. Braunite, a hard, dense black or brownish-black mineral with a dull or submetallic luster, has been mined in Plumas County and in Humboldt County.

#### Principal Manganese Minerals Occurring in California Ores

	SPECIFIC GRAVITY	HARDNESS	CHEMICAL FORMULA	PERCENT MANGANESE
Pyrolusite	4.5-5.0	2-5 (rarely up to 6.5)	MnO <sub>2</sub>	63.2
Psilomelane type	4.3-4.7	5-6.5	See below	55 to 65
Hausmannite	4.9	5-5.5	Mn <sub>3</sub> O <sub>4</sub>	72.1
Braunite	4.8	6-6.5	3 Mn <sub>2</sub> O <sub>3</sub> · 2 Mn <sub>2</sub> O <sub>4</sub>	66
Manganite	4.3	4	Mn <sub>2</sub> (OH)O	62.1

PRIMARY MINERALS	SPECIFIC GRAVITY	HARDNESS	CHEMICAL FORMULA	PERCENT MANGANESE
Rhodochrosite	4.0-4.6	3-4.5	MnCO <sub>3</sub>	47.8
Rhodolite	4.3-4.6	5-6.5	Mn <sub>2</sub> SiO <sub>4</sub>	32
Braunite	2.8	—	3 Mn <sub>2</sub> (OH)O <sub>2</sub>	60 (approx.)
Nodulite	2.8	—	Manganiferous opal	—
Wad	4.18	6-7.5	Mn <sub>2</sub> (OH) <sub>2</sub> · SiO <sub>2</sub> · nH <sub>2</sub> O	33

\* Psilomelane type is a group name for several different minerals on the basis of which psilomelane but which may be distinguished by X-ray studies. These include coronadite, cryptomelane, hollandite, and the true psilomelane. The group composed of Mn<sub>2</sub> with a different species, Pb, Ba, Bi, Hg, also O, Zn, to be.

Wad is a group name for various soft manganese oxide of low specific gravity.

Other manganese minerals reported from California are: deposits of lepidolite, pyrochroite, amorphous, psilomelane, manganite, and kumpite.

Rhodochrosite occurring in veins is commonly light pink, but as a primary mineral in the bedded Franciscan deposits it is usually gray. The pulverized mineral effervesces in hydrochloric acid, however, ore should be taken to distinguish this from the more violent effervescence of calcite, which is often present in cracks and interstices in California ores. In common with all the other primary minerals to be described, rhodochrosite becomes coated with a film of black manganese oxide upon exposure to the agents of weathering. Rhodochrosite is acceptable as a source of manganese after calcining.

Rhodolite is pink or reddish, usually occurring in fine, to coarse-grained, bladed crystals. It may be distinguished from pink rhodochrosite by its greater hardness, and by its failure to effervesce in acid. Rhodolite is the common primary mineral of the Sierra Nevada deposits. It has no value at present as a source of manganese, but has sometimes been used for geos or ornamental stones. Braunite and nodulite are by no means manganese silicates, which are difficult to distinguish from one another without X-ray studies. They are yellow or brown, dense, massive, and have a waxy or resinous luster. They are commonly mixed with more or less chert and with rhodochrosite. They are the primary minerals in many of the Franciscan deposits. They are not utilized at present as a source of manganese. Spessartite, the manganese garnet, occurs in brownish dolomitic crystals. It weathers to a friable, granular brownish-black oxide ore. Spessartite, alone or accompanied by rhodolite, forms the primary mineral for many of the Sierra Nevada deposits. It has no value as a source of manganese.

#### Types of Deposits

The majority of the deposits in California occur in one of three ways: (1) in chert of the Franciscan formation, in the Coast Ranges; (2) in metamorphosed chert in older rocks, in the Sierra Nevada and Klamath Mountains; and (3) in fissures, mostly in volcanic rocks and fanglomerate, in the Mojave Desert and Basin Ranges.

#### Franciscan Deposits

Most of the manganese deposits in the Coast Ranges are sedimentary deposits enclosed in chert of the Franciscan formation (Upper Jurassic). The ore generally occurs in massive lenses of chert enclosed in thin-bedded chert. Most of the orebodies are lens-shaped something like a pancake. The orebody at the Lodi mine is 800 feet long, but most of the others are less than 200 feet long, and less than 30 feet thick. The orebodies lie parallel to the bedding of the enclosing rocks. Most of the Franciscan rocks have been tilted at high angles, so that the orebodies commonly dip steeply and outcrop in long, narrow belts at the surface.

The primary ore in the Franciscan deposits is composed of gray rhodochrosite and brown limonite, or other brown manganese silicates, in varying proportions. The highest-grade ore is formed from rhodochrosite. These minerals are oxidized to black manganese oxide near the surface, and the depth of oxidation is an important factor in determining the value of the deposits. The depth of oxidation is generally greatest where the rate of erosion is slowest. Oxide ore extends as much as 200 feet below some round-topped hills, but as little as 10 feet in the bottoms of nearby canyons. In the more rugged mountains of northern California the depth of oxidation is generally less than in the more subdued hills farther south.

The higher-grade orebodies contain massive black-oxide ore, but the lower-grade bodies contain disseminated ore. Many of the larger orebodies have a high-grade portion surrounded by lower-grade disseminated ore.

It is believed that the manganese was deposited originally in basins on the sea floor along with silica, which formed the enclosing chert.

#### Metamorphosed Deposits (Rhodonite Deposits)

The deposits in the Sierra Nevada and the Klamath Mountains are of the same general type as those in the Franciscan formation and are believed to have formed in the same way, except that they occur in older rocks which have been metamorphosed. In some of these deposits the enclosing rocks still have the characteristics of chert, in others the chert has been recrystallized into fine-grained quartzite. The main effect of the metamorphism on the manganese is the transformation of the primary minerals into rhodonite, and in some places spessartite. In the less metamorphosed deposits rhodochrosite and bementite are still present, along with more or less rhodonite.

The rhodonite deposits occur in lenses which have been tilted, and they have approximately the same shape as the Franciscan bodies. The depth of oxidation is usually less than in the Franciscan deposits, however, because rhodonite and spessartite are less readily oxidized than rhodochrosite. In some of the deposits the oxide zone extends only a few inches below the surface, and such deposits have little value as a source of manganese, inasmuch as neither rhodonite nor

spessartite may be utilized commercially at the present time.

Rhodonite deposits occur in the Calaveras series (Carboniferous) and the Anador group (Jurassic) in the Sierra Nevada; in Paleozoic or Mesozoic rocks in the Klamath Mountains; in the Pelona schist (pre-Cambrian) near Palmdale; and in Tertiary (?) slates near Lake Elsinore.

#### Fissure Deposits

The manganese deposits of the Mojave Desert and Basin Ranges occur in fissures cutting various types of rocks. The deposits consist most commonly of brecciated zones cemented, unprecipitated, and only replaced by manganese oxide. In some places there are nodular veins of finely solid manganese oxide. Veins of white calcite, later in origin than the manganese, are common. Some of the deposits grade downward into black or brown calcite impregnated with manganese oxide.

Although the fissures may extend for a mile or so in length, the individual ore shoots commonly range from a few feet to 500 feet in length, and from a few inches to 10 feet in width. The depth of mineralization is generally not great, ranging from less than 10 feet to as much as 100 feet.

The fissure deposits are most common in volcanic rocks and in fanglomerate, but they are also known in limestone and in granite.

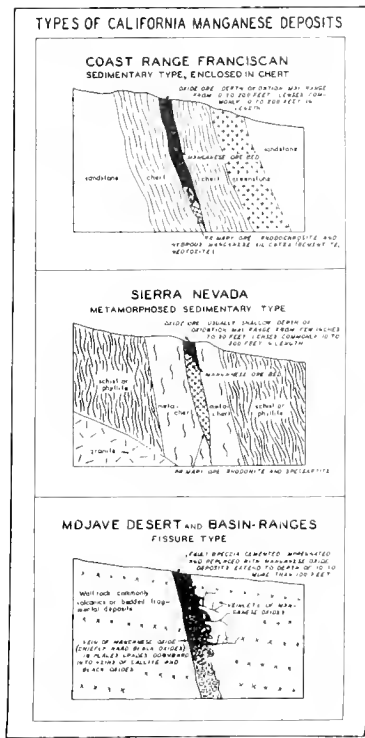
The average manganese content of the deposits mined is from 15 to 30 percent, but in some places the hard oxide ore can be hand-sorted to give a product containing 40 to 45 percent of manganese.

#### Other Types

Other types of manganese deposits known in California, in addition to the principal ones described above, include large low-grade bedded wad deposits, in the desert region, fanglomerate cemented by manganese oxide, adjacent to fissures, a variation of the fissure type of deposit, replacement deposits, and a few miscellaneous superficial deposits of small size and low grade. Deposits of manganiferous iron ore occur in Franciscan chert and in metamorphosed older chert; and one manganiferous iron-ore deposit occurs as a replacement of Franciscan limestone.

#### Distribution in California

Manganese deposits are widely scattered over the state. Some 65 deposits are known to occur in 44 counties. However, the majority of these are small and of low grade, or both. Production has been recorded from nearly 170 properties in 31 counties, slightly over half the total number of counties in the state. In the Coast Ranges, which have accounted for about 80 percent of the production in the state, the manganese deposits in Franciscan cherts are grouped mainly in four areas: (1) the Mad River Valley in western Trinity County; (2) east-central Mendocino County and the adjoining part of Lake County; (3) the mountains southwest and south of Tracy, in San Joaquin, Alameda, Santa Clara, and Stanislaus counties; and (4) the western part of San Luis Obispo County. Metamorphosed deposits (mainly rhodonite deposits) are found in the Klamath Mountains, in Siskiyou and eastern Trinity counties, and in a belt along the western slope of the Sierra Nevada from Plumas County at the north to Kern County at the south. Fissure deposits are found chiefly in southern Inyo County, San Bernardino County, and the eastern parts of Riverside and Imperial counties.



SEDIMENTARY ROCKS		IGNEOUS ROCKS	
QUATERNARY	RECENT	QUATERNARY	RECENT
Qs	Sand dunes	Qnc	Cinder cones
Qal	Alluvium	Qmv	Volcanic mud flows
Qsl	Salt deposits	Qrv	Recent volcanics
Ql	Terrace deposits	Qrv	Recent rhyolite
Qg	Glacial deposits	Qva	Recent andesite
Ql	Pleistocene lake beds	Qvb	Recent basalt
Qm	Pleistocene marine sediments	Qv	Pleistocene volcanics
Op	Quaternary and Upper Pleistocene sediments	Qv	Pleistocene rhyolite
Pc	Undivided Pliocene non-marine sediments	Qv	Pleistocene andesite
Pu	Upper Pliocene marine sediments	Qv	Pleistocene basalt
Puc	Upper Pliocene non-marine sediments	Qv	Undivided Cenozoic volcanics
Pml	Middle and Lower Pliocene marine sediments	Pv	Pliocene volcanics
Tib	Tertiary lake beds	Pv	Pliocene rhyolite
Qtc	Cenozoic on marine sediments	Pv	Pliocene andesite
Mc	Undivided Miocene non-marine sediments	Pv	Pliocene basalt
Muc	Upper Miocene non-marine sediments	Pv	Lower Pliocene volcanics and interbedded sediments
Mmc	Middle Miocene non-marine sediments	Mv	Miocene volcanics
Mu	Upper Miocene marine sediments	Mv	Miocene rhyolite
Mm	Middle Miocene marine sediments	Mv	Miocene andesite
Ml	Lower Miocene marine sediments	Mv	Miocene basalt
Qc	Oligocene volcanics	Qc	Oligocene volcanics
Tg	Tertiary volcanic	Tg	Undivided Tertiary volcanics
Euc	Upper Eocene non-marine sediments	Tv	Tertiary rhyolite
		Tv	Tertiary andesite

#### CALIFORNIA MANGANESE PRODUCTION - UNITED STATES PRODUCTION & CONSUMPTION - STEEL PRODUCTION

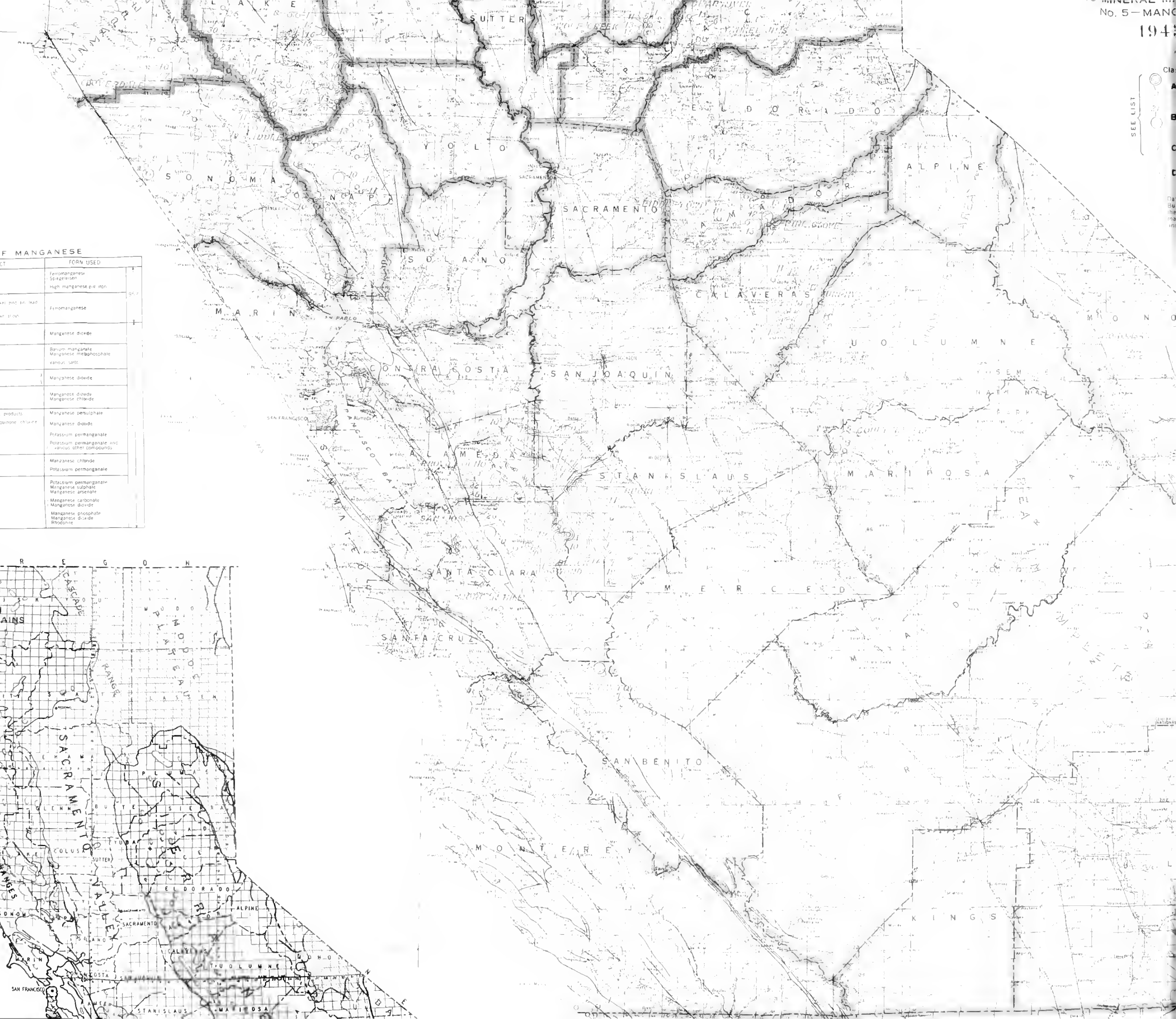




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# USES OF MANGANESE

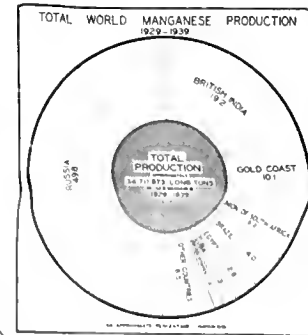
USE OR PRODUCT		FORM USED
METALLURGICAL	Alloy in high grade steel	Ferromanganese Spiegeleisen
	Purifier in smelting	High manganese pig iron
	Alloys with copper, aluminum, nickel, zinc, tin, lead, magnesium, iron, etc.	Ferromanganese
	Purifier in smelting nearly all known ores	
CHEMICAL	Decolorizer in dry cells	Manganese dioxide
	Green and violet color	Barium manganate Manganese metaphosphate various salts
	Drier	Manganese dioxide
	Decolorizing material	Manganese dioxide Manganese chloride
FERTILIZER	Order in manufacture of organic products	Manganese persulfate
	Order in manufacture of hydroquinone, chlorine, bromine, and iodine	Manganese dioxide
	Purifying gases	Potassium permanganate
	Laboratory chemicals	Potassium permanganate and various other compounds
MISCELLANEOUS	Brown or bronze dye	Manganese chloride
	Bleach	Potassium permanganate
	Disinfectant Fertilizer Insecticide	Potassium permanganate Manganese sulphate Manganese arsenate
	Welding rod coating	Manganese carbonate Manganese dioxide
	Protective coating on steel	Manganese phosphate
	Porcelain enamel	Manganese dioxide
	Jewelry and ornamental stones	Rhodolite











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